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WIND VELOCITY PROFILES MEASURED BY THE SMOKE-TRAIL METHOD AT WALLOPS ISLAND, VIRGINIA, 1963 AND 1964

by Robert M. Henry and Robert W. Miller

Langley Research Center
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SUMMARY

Forty-five detailed wind velocity profiles measured by the smoke-trail technique at Wallops Island, Va., during 1963 and 1964 are presented. These profiles were obtained for heights from 0.5 to 30 kilometers. Two second-stage profiles for heights from 39 to 58 kilometers are also included. The profiles cover all seasons and the characteristics are generally similar to those of previously published smoke-trail profiles. Wind velocities in excess of the 99-percent extreme value are included. Closely spaced soundings show only small variations over horizontal distances of 2 kilometers and time intervals of $1\frac{1}{2}$ hours.

INTRODUCTION

Knowledge of the small-scale variations of the wind velocity with altitude is needed for dynamic response and control studies of vertically launched missiles and space systems. These small-scale variations cannot be obtained from present-day conventional balloon sounding methods because of spurious balloon motions and large tracking errors. (Both of these errors have been substantially reduced but not eliminated in several recently developed special purpose balloon systems.) Also, balloons may travel a large distance horizontally in the altitude range of interest.

To provide information on these small-scale variations, the smoke-trail wind measurement technique described in reference 1 was developed at the NASA Langley Research Center. This technique not only provides information on small-scale wind fluctuations but also provides it along a typical missile trajectory.

Preliminary testing of the smoke-trail technique was begun at the NASA Wallops Station, Wallops Island, Va., in 1959 and the data collected through 1962 were published in reference 2. Results of similar tests at the Eastern Test Range during 1962 are presented in reference 3. The purpose of this present publication is to make available the basic data from smoke-trail measurements at the Wallops Island range during 1963 and 1964.

MEASUREMENT TECHNIQUE

The basic technique for obtaining detailed wind profiles by the smoke-trail method consists of photographing a visible trail formed by releasing a suitable chemical from a rocket during its flight. The photographs are taken from two camera sites each approximately 16 kilometers from the launch point and approximately 90° apart. The motion of the trail is determined from measurements of its image on successive pairs of simultaneous photographs. The fundamental procedures are described in references 1 and 2. Figure 1 shows a pair of such photographs taken simultaneously at the two camera sites (Miona and Battle Point) at the Wallops Island range. Figure 2 illustrates three such trails produced by a salvo of smoke rockets.

The data in this report are mainly derived from smoke trails produced during the coasting portion of flights of Nike smoke vehicles. These vehicles, described in reference 4, are fin-stabilized Nike rocket motors with a smoke-producing nose cone. The smoke-producing chemical used in most of the firings was titanium tetrachloride (FM). (See ref. 5.) Three profiles are included which were derived from photographing the exhaust trails of Scout vehicles.

The technique of data preparation is given in references 2 and 3, and the machine processing of the data is discussed in an appendix of these references. Briefly, the process consists of (1) the selection of simultaneous photographs taken at successive 30-second intervals, (2) redundant reading and plotting of smoke-trail images for minimization of errors, and (3) computation and final plotting of velocity profiles.

RESULTS AND DISCUSSION

Plots of west-to-east and south-to-north components of wind velocity as a function of altitude are shown in figures 3 to 47. Values of wind velocity are computed for every 25-meter altitude increment and connected with straight-line segments; this gives the appearance, on the scale used, of a continuous curve. Table I shows the figure number, Langley smoke-trail identification number, date and time of launching, altitude range covered, and the maximum west-to-east velocity component.

The data for the 45 profiles reported herein, plus wind speed and direction and wind-shear values, are also available on request from the NASA Langley Research Center on punched cards or in tabular form.[1] The format of the data and the units used are

[1]Requests should be directed to the Langley Research Center, Hampton, Virginia 23365, and should include the author, title, and code number of this paper and specific profiles desired.

illustrated by the sample tabulation in table II. In tabular form, each profile is identified by a trail number, date and time of launch, altitude increment used in computation, time increments over which the data were taken, and camera and picture (frame) identification.

To provide pressure, temperature, and humidity data, radiosonde measurements were made at Wallops Island within 6 hours of each of the smoke-trail firings. The results are not included in this report but are available from the National Weather Records Center, Federal Building, Asheville, North Carolina 28801.

As shown in table I, the firings occurred during a 2-year period with measurements being obtained during all seasons of the year. The characteristics of these profiles are generally similar to those of the profiles presented in references 2 and 3. The profiles obtained from the 42 Nike smoke vehicle and the 3 Scout first-stage exhaust trails varied in length from 800 to 29 300 meters with a minimum altitude of 525 meters and a maximum altitude of 29 800 meters. Two Scout second-stage exhaust trails covered an altitude range from 39 300 to 57 900 meters. The maximum west-to-east velocity components from the Nike trails and Scout first-stage trails ranged from 3 to 71 meters per second. The west-to-east wind velocity component from one of the Scout second-stage trails attained a maximum of 130.6 meters per second at an altitude of 54 125 meters.

The maximum west-to-east velocity component of almost 70 meters per second measured during the three simultaneous firings covered by figures 3, 4, and 5 equals the 99 percent highest component (the value which will not be exceeded 99 percent of the time) for the month of April and that of about 50 meters per second in figures 38 and 39 exceeds the 95 percent highest component for October based on the data from reference 6. No comparison can be made concerning the wind velocity of about 131 meters per second measured from the second-stage portion of trail 073 (fig. 47(c)) inasmuch as this velocity occurred at an altitude above that considered in reference 6.

The first three trails, 028, 029, and 030, listed in table I and illustrated in figure 2, were produced by a salvo of smoke rockets fired to compare three different smoke-producing agents. Details of these tests are discussed in references 5 and 7. Figure 2 shows the character of the trails up to 22 000 meters approximately 1 minute after launching. These trails provide three independent measurements of the wind profile obtained at the same time but at different launch sites. The two trails on the right were about 1/2 kilometer apart and the two outermost trails were about 2 kilometers apart. A close examination of the sequence of photographs from which figure 2 was taken (ref. 5) indicates that the trails are almost exact images of one another for the several minutes of time covered by the sequence of pictures. These photographs give graphic evidence that the characteristics of the wind flow field were very consistent within the region sampled for this case and that under some circumstances the spatial wind variations may be quite small.

The component profiles reduced from these trails are given in figures 3, 4, and 5. Only minor differences can be detected in the west-to-east component of the three profiles. In the south-to-north component, the three profiles match well except for a spike at about 7 kilometers on trail 028. This spike is not present on trails 029 or 030. Although the data readout and reduction operations for the pertinent photographs have been carefully checked, this feature in trail 028 is considered somewhat questionable.

A similarity of profile shape over a lapse of time is demonstrated by three pairs of trails which are compared in figures 48, 49, and 50. Two profiles having a time difference of about $1\frac{1}{2}$ hours are shown in figure 48. Although the velocities involved are small, the resemblance between the two profiles is quite good. In figure 49 a Nike smoke profile is compared with a profile obtained from the exhaust trail of a Scout vehicle; again there was a time difference of $1\frac{1}{2}$ hours. The Scout profile is short because of cloud interference on the range, but the velocities involved are considerably larger than those in figure 48. The profiles from two trails produced about $\frac{1}{2}$ hour apart are shown in figure 50. In these profiles, the south-to-north component is the larger and considerable shear is encountered at about 12 kilometers. As expected, the profile differences are even smaller than the differences in profiles obtained $1\frac{1}{2}$ hours apart.

Another interesting profile is shown by trail 065 (fig. 40). This profile exhibits three large peaks: a very narrow peak at about 14 kilometers and two wider peaks at about 15.5 kilometers and 17 kilometers. To examine the reliability of these peaks, especially the extremely sharp peak at 14 kilometers, profiles were reduced from photographs taken by all four possible camera pairs from the two cameras at each camera site. The results of these four computations are shown in figure 51. All four computations indicate a peak at 14 kilometers but some differences are noted as to its precise shape and magnitude. The two broader peaks at 15.5 kilometers and 17 kilometers are seen to have very similar shapes and magnitudes in all four profiles and it appears that the data are quite reliable concerning these two peaks. These two broader peaks are similar to the double peaks in trail 008 shown in reference 2.

CONCLUDING REMARKS

Forty-five detailed wind velocity profiles measured by the smoke-trail technique at the Wallops Island range during 1963 and 1964 are presented. The characteristics of these profiles are generally similar to those in NASA Technical Notes D-2937 and D-3289. The altitude ranges of the individual profiles vary, but the overall range is roughly from 500 to 29 800 meters; two measurements from Scout second-stage exhaust trails were obtained between 39 300 and 57 900 meters. The measurements were made under a variety of seasonal conditions with the maximum west-to-east wind velocity

component ranging up to about 70 meters per second in the lower altitude range and up to 130 meters per second in the higher altitude range. The results show that under some circumstances wind variations may be quite small over horizontal distances at least up to 2 kilometers and time intervals up to $1\frac{1}{2}$ hours.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., August 4, 1967,
709-05-00-02-23.

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TABLE I.- WALLOPS ISLAND WIND PROFILES FOR 1963 AND 1964

Figure	Trail identification	Date	EST	Altitude range, km	Maximum west-to-east component of velocity, m/sec
3	[a]028	4/25/63	1458	4.0 to 20.0	70
4	[a]029	4/25/63	1458	4.0 to 11.4	70
5	[a]030	4/25/63	1458	4.0 to 17.0	71
6	031	8/15/63	1811	3.6 to 19.5	45
7	032	9/19/63	1514	4.2 to 20.2	10
8	033	9/19/63	1648	4.2 to 20.2	12
9	034	9/23/63	1300	2.9 to 18.8	54
10	035	10/1/63	1634	5.6 to 20.0	21
11	036	10/4/63	1314	3.9 to 20.7	36
12	037	10/11/63	1309	5.5 to 22.0	23
13	038	10/15/63	1438	2.7 to 16.4	11
14	039	11/12/63	1520	4.2 to 19.2	54
15	040	1/22/64	1527	3.8 to 21.7	37
16	041	1/29/64	1419	3.5 to 20.1	50
17	042	2/4/64	1320	3.1 to 19.4	30
18	043	3/13/64	1336	4.7 to 20.5	41
19	044	3/17/64	1440	4.2 to 16.8	41
20	[b]045	3/27/64	1226	2.2 to 6.0	[c]46
21	046	3/27/64	1404	2.7 to 14.4	62
22	047	4/9/64	1629	2.9 to 18.9	49
23	048	4/17/64	1344	3.7 to 17.2	23
24	049	5/4/64	1315	3.3 to 17.9	12
25	050	5/5/64	1234	3.6 to 17.8	12
26	051	5/6/64	1318	3.7 to 18.6	4
27	052	5/6/64	1343	3.7 to 14.4	3
28	053	5/19/64	1322	3.6 to 13.5	20
29	054	5/22/64	1443	5.2 to 15.1	8
30	055	6/11/64	1334	4.7 to 14.9	23
31	056	7/30/64	1617	5.7 to 16.3	26
32	057	8/14/64	1754	5.0 to 16.8	45
33	058	8/19/64	1311	4.0 to 16.5	48
34	059	9/3/64	1336	2.1 to 16.1	9
35	060	9/4/64	1201	2.9 to 15.5	16
36	061	9/9/64	1235	2.6 to 15.0	15
37	062	9/15/64	1258	5.6 to 18.9	36
38	063	9/25/64	1512	4.0 to 17.7	50
39	064	10/13/64	1426	4.2 to 18.4	49
40	065	10/22/64	1156	5.3 to 19.1	43
41	066	10/30/64	1328	4.2 to 15.4	24
42	[b]067	11/6/64	0702	.6 to 1.4	[c]5
	[b]067			16.9 to 23.5	[c]9
	[d]067			40.3 to 48.1	60
43	068	11/13/64	1510	4.3 to 18.9	52
44	069	11/24/64	1310	2.9 to 18.0	55
45	070	12/1/64	1553	2.7 to 17.0	48
46	071	12/8/64	1313	2.8 to 19.9	52
47	[b]073	12/15/64	1520	.5 to 29.8	56
	[d]073			39.3 to 57.9	131

[a]Trails 028, 029, and 030 obtained from simultaneous launches.

[b]Scout first stage.

[c]Maximum may not have been measured.

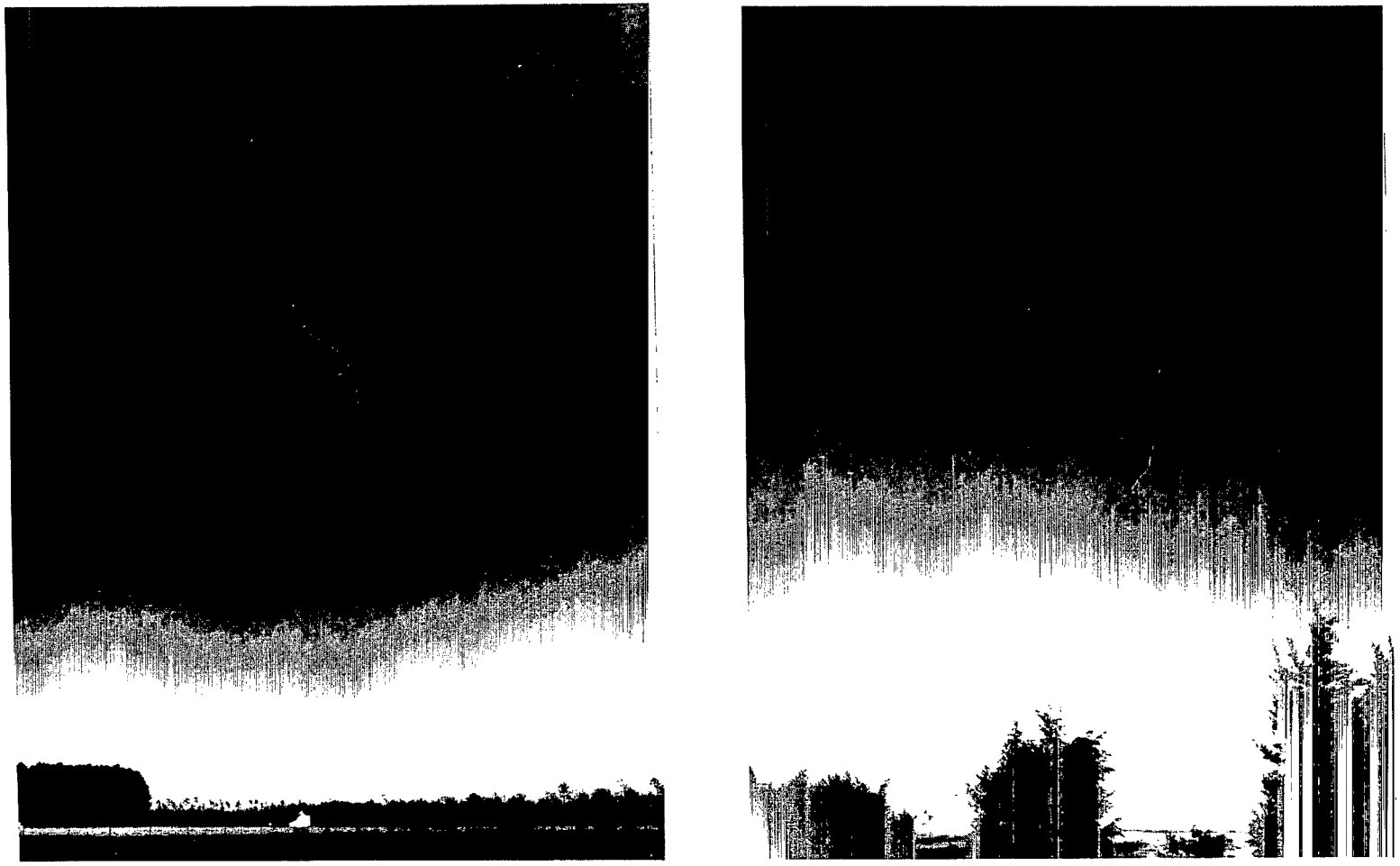
[d]Scout second stage.

TABLE II.- SAMPLE TABULATION

WALLOPS SMOKE-TRAIL NO. 73 LAUNCHED 12/15/64 1520EST DELTA T 60 SECS
MIGNA RIGHT BATTLE POINT LEFT FRAMES 29 AND 39

Z (METERS)	VX (MPS)	VY (MPS)	V (MPS)	THETA (DEGREES)	SHEAR X (/SEC)	SHEAR Y (/SEC)	SHEAR V (/SEC)	SHEAR M (/SEC)
53700	106.0	24.3	108.70	257.10	0.006	-0.020	0.021	0.001
53725	105.6	23.9	108.30	257.25	-0.013	-0.015	0.020	0.016
53750	105.1	23.6	107.72	257.36	-0.021	-0.013	0.025	0.023
53775	104.6	23.2	107.14	257.47	-0.021	-0.013	0.025	0.023
53800	104.1	22.9	106.62	257.60	-0.018	-0.014	0.023	0.021
53825	104.5	22.2	106.79	258.01	0.013	-0.028	0.031	0.007
53850	105.4	20.7	107.46	258.89	0.039	-0.059	0.071	0.027
53875	106.4	19.2	108.16	259.76	0.039	-0.059	0.071	0.028
53900	109.2	17.2	110.57	261.03	0.112	-0.079	0.137	0.097
53925	111.6	16.2	112.79	261.76	0.096	-0.043	0.105	0.089
53950	114.0	15.1	115.02	262.46	0.096	-0.043	0.105	0.089
53975	116.4	14.0	117.27	263.13	0.096	-0.043	0.105	0.090
54000	118.8	13.0	119.53	263.78	0.096	-0.043	0.105	0.091
54025	121.4	11.9	121.93	264.42	0.101	-0.044	0.110	0.096
54050	125.7	10.6	126.15	265.17	0.174	-0.049	0.181	0.169
54075	127.9	11.0	128.36	265.09	0.087	0.015	0.089	0.088
54100	130.1	11.4	130.56	265.01	0.087	0.015	0.089	0.088
54125	130.6	11.6	131.13	264.93	0.022	0.009	0.024	0.023
54150	130.5	11.8	131.03	264.85	-0.005	0.007	0.008	0.004
54175	130.4	11.9	130.93	264.77	-0.005	0.007	0.008	0.004
54200	130.2	12.1	130.81	264.69	-0.006	0.006	0.008	0.005
54225	130.1	12.2	130.67	264.62	-0.006	0.006	0.009	0.006
54250	129.9	12.4	130.52	264.55	-0.006	0.006	0.009	0.006
54275	129.8	12.5	130.38	264.48	-0.006	0.006	0.009	0.006
54300	129.6	12.7	130.24	264.41	-0.006	0.006	0.009	0.006
54325	129.5	12.8	130.10	264.34	-0.006	0.006	0.009	0.006
54350	129.3	13.0	129.96	264.27	-0.006	0.006	0.009	0.006
54375	129.2	13.1	129.82	264.20	-0.006	0.006	0.009	0.006
54400	129.0	13.3	129.68	264.13	-0.006	0.006	0.009	0.006
54425	128.8	13.4	129.54	264.06	-0.006	0.006	0.009	0.006
54450	128.7	13.6	129.40	263.99	-0.006	0.006	0.009	0.006
54475	128.5	13.7	129.26	263.92	-0.006	0.006	0.008	0.005
54500	128.4	13.8	129.14	263.86	-0.005	0.005	0.007	0.005
54525	128.3	13.9	129.02	263.81	-0.005	0.005	0.007	0.005
54550	128.1	14.0	128.89	263.75	-0.005	0.005	0.007	0.005
54575	128.0	14.1	128.77	263.69	-0.005	0.005	0.007	0.005
54600	127.9	14.3	128.65	263.64	-0.005	0.005	0.007	0.005
54625	127.7	14.4	128.53	263.58	-0.005	0.005	0.007	0.005
54650	127.6	14.5	128.40	263.52	-0.005	0.005	0.007	0.005
54675	127.4	14.6	128.28	263.47	-0.005	0.005	0.007	0.005
54700	127.3	14.7	128.16	263.41	-0.005	0.005	0.007	0.005

Z	altitude, meters
VX	west-to-east component of velocity, meters per second
VY	south-to-north component of velocity, meters per second
V	magnitude of resultant velocity, meters per second
Theta	direction from which wind is blowing, degrees
Shear X	$\delta VX/\delta Z$, per second
Shear Y	$\delta VY/\delta Z$, per second
Shear M	$\delta V/\delta Z$, per second
Shear V	$\sqrt{\left(\frac{\delta VX}{\delta Z}\right)^2 + \left(\frac{\delta VY}{\delta Z}\right)^2}$, per second



(a) Camera site I (Miona).

(b) Camera site II (Battle Point).

Figure 1.- Smoke trail as photographed from two camera sites. L-67-6659

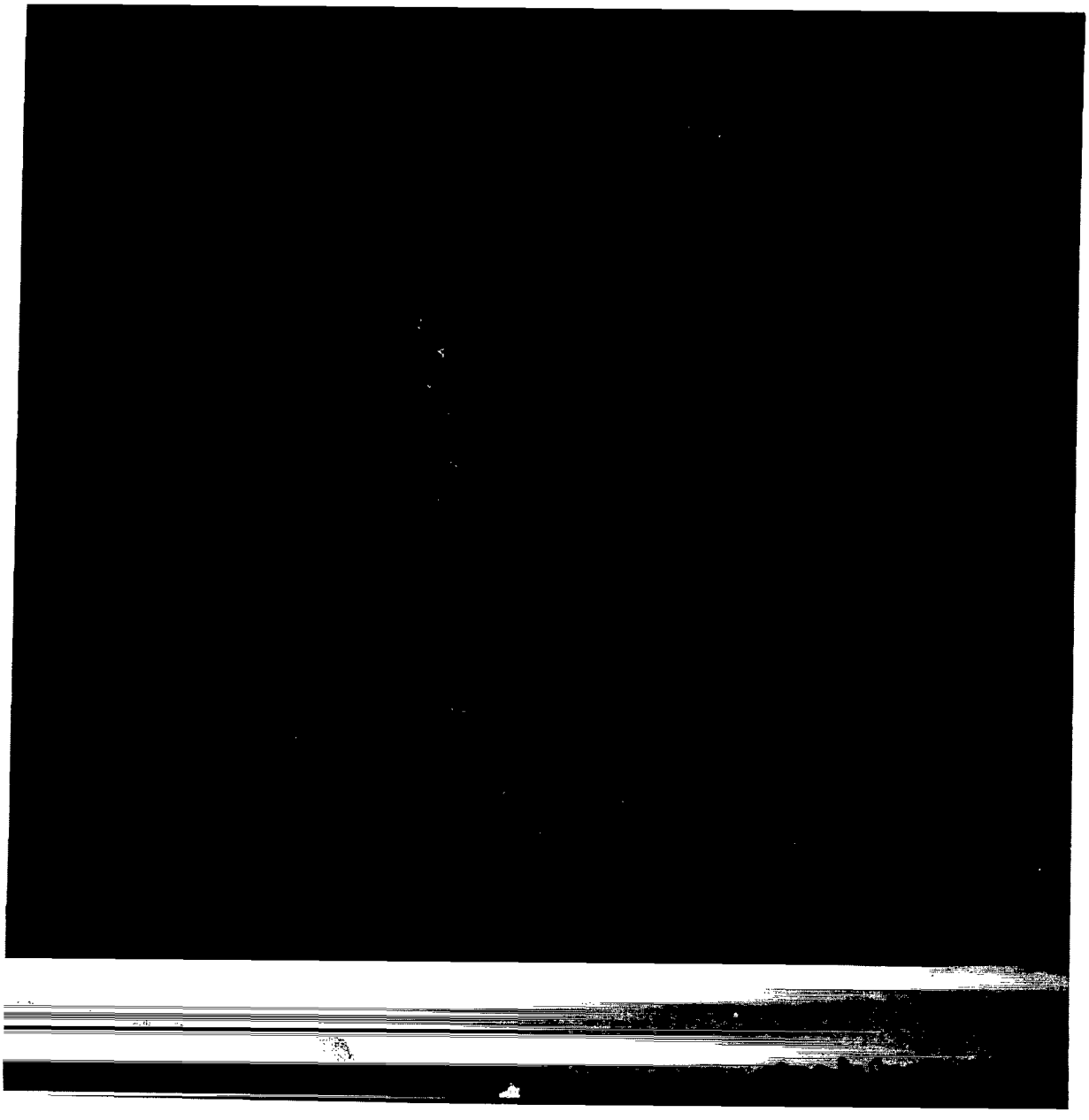
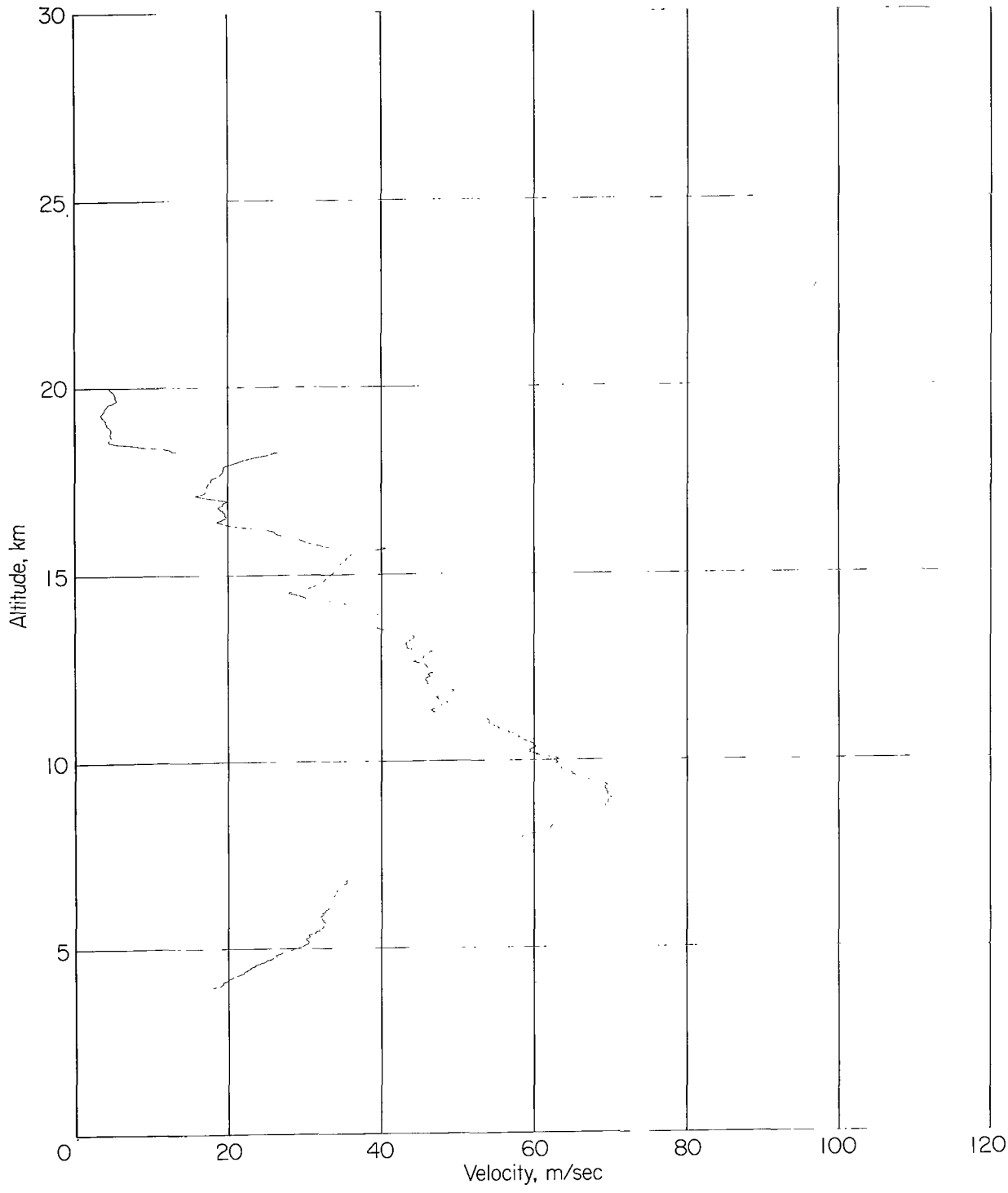
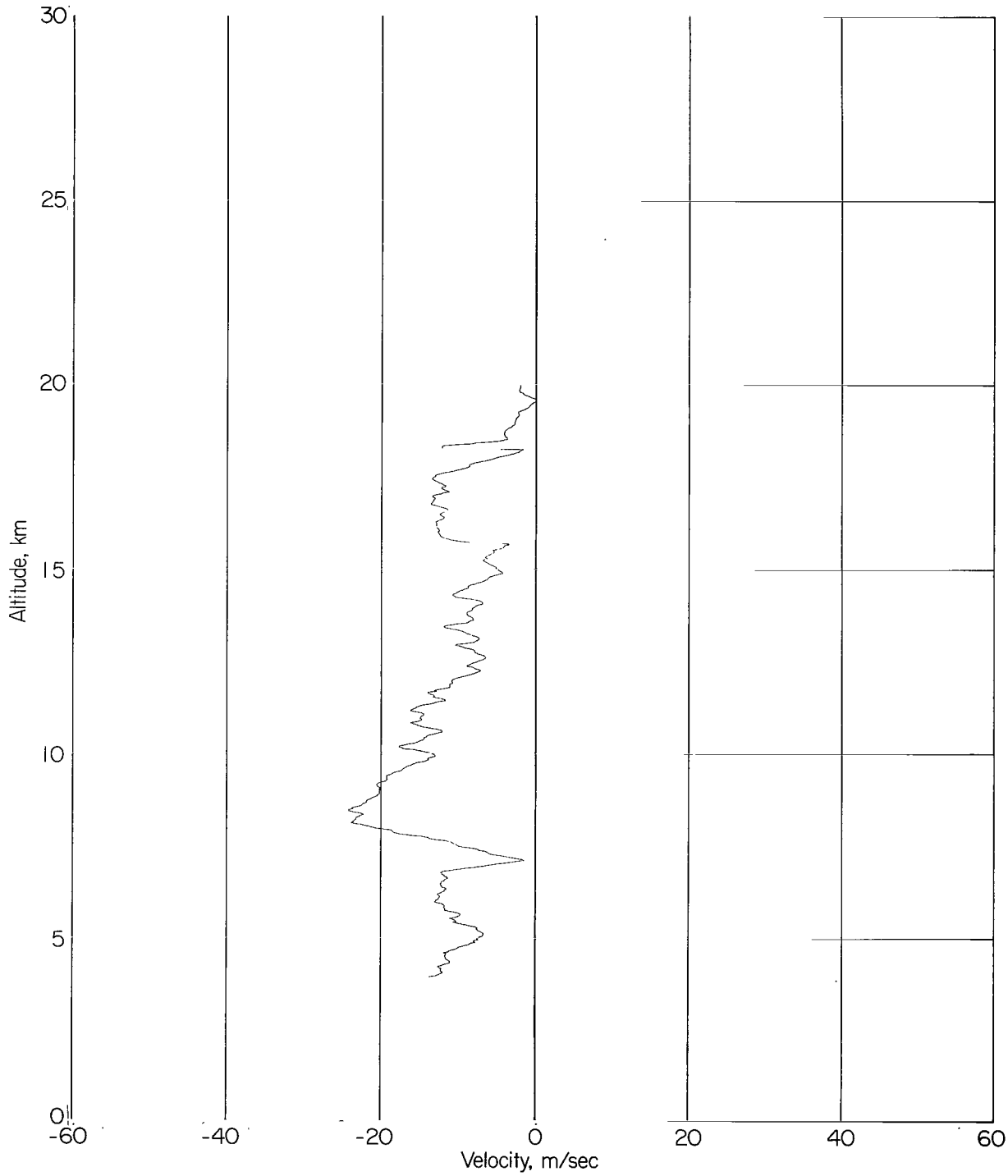


Figure 2.- Smoke rocket salvo. L-67-6660



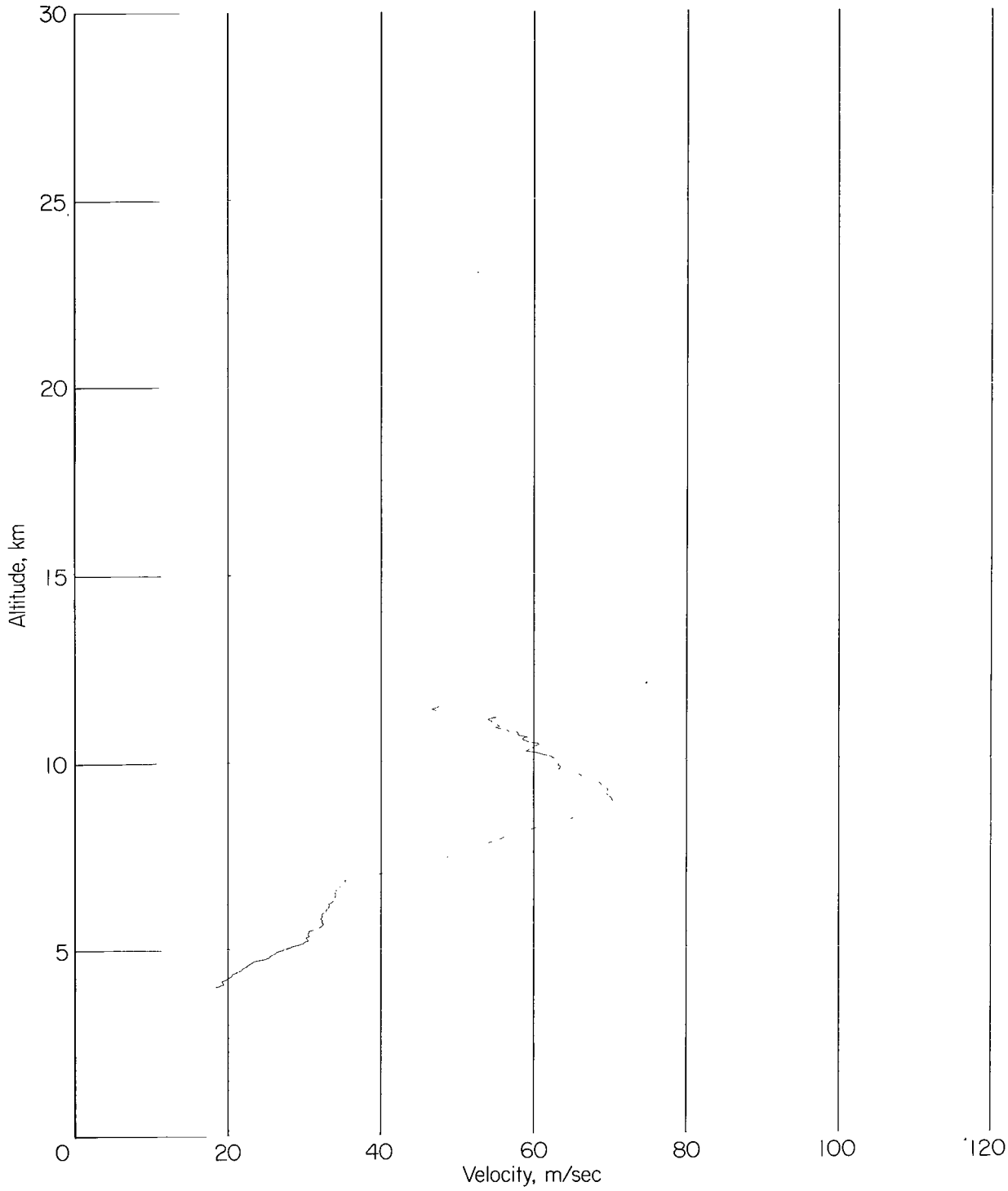
(a) West-to-east velocity component.

Figure 3.- Wind profile of smoke trail 028 obtained April 25, 1963. Time interval, 60 seconds; height interval, 25 meters.



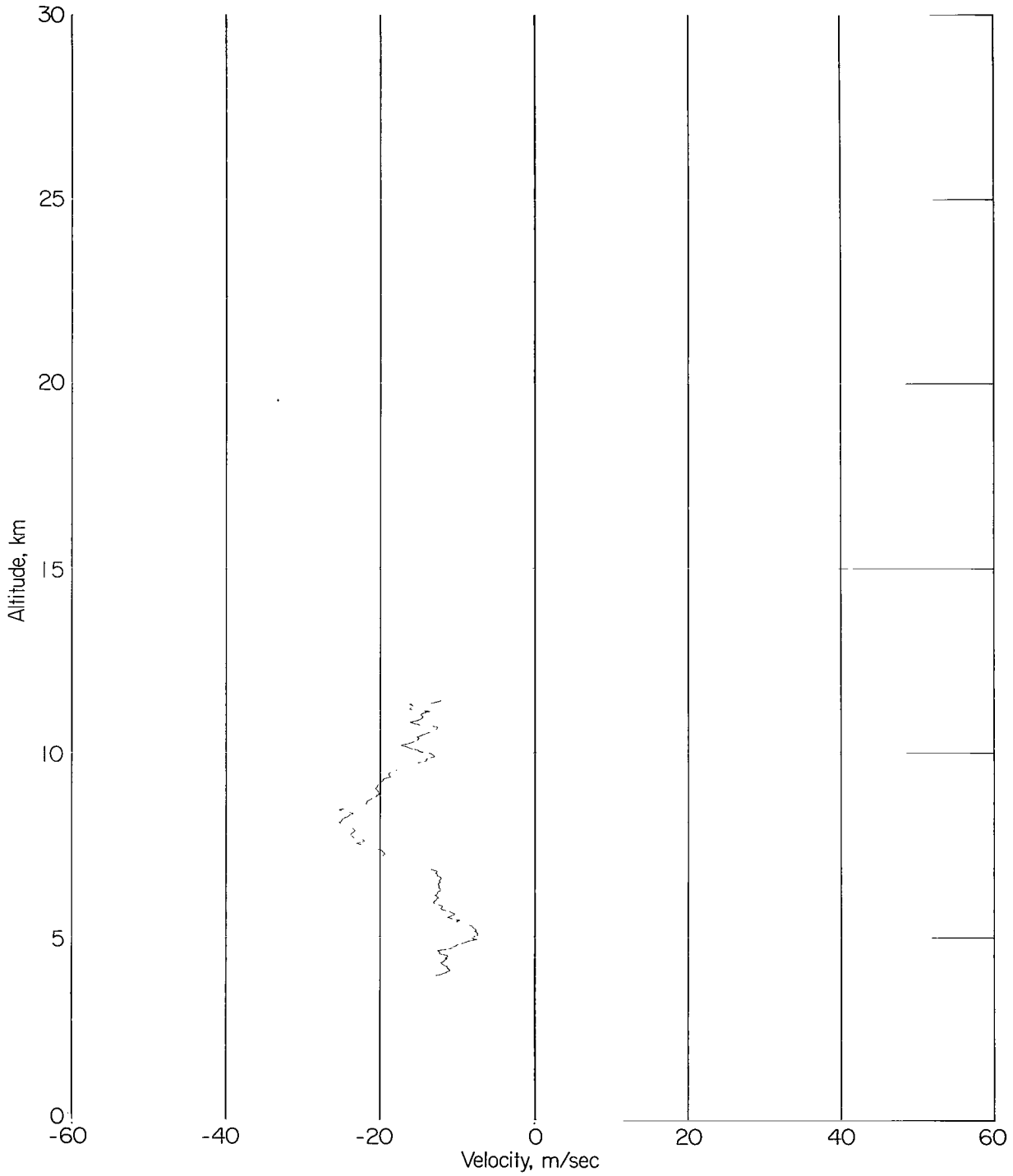
(b) South-to-north velocity component.

Figure 3.- Concluded.



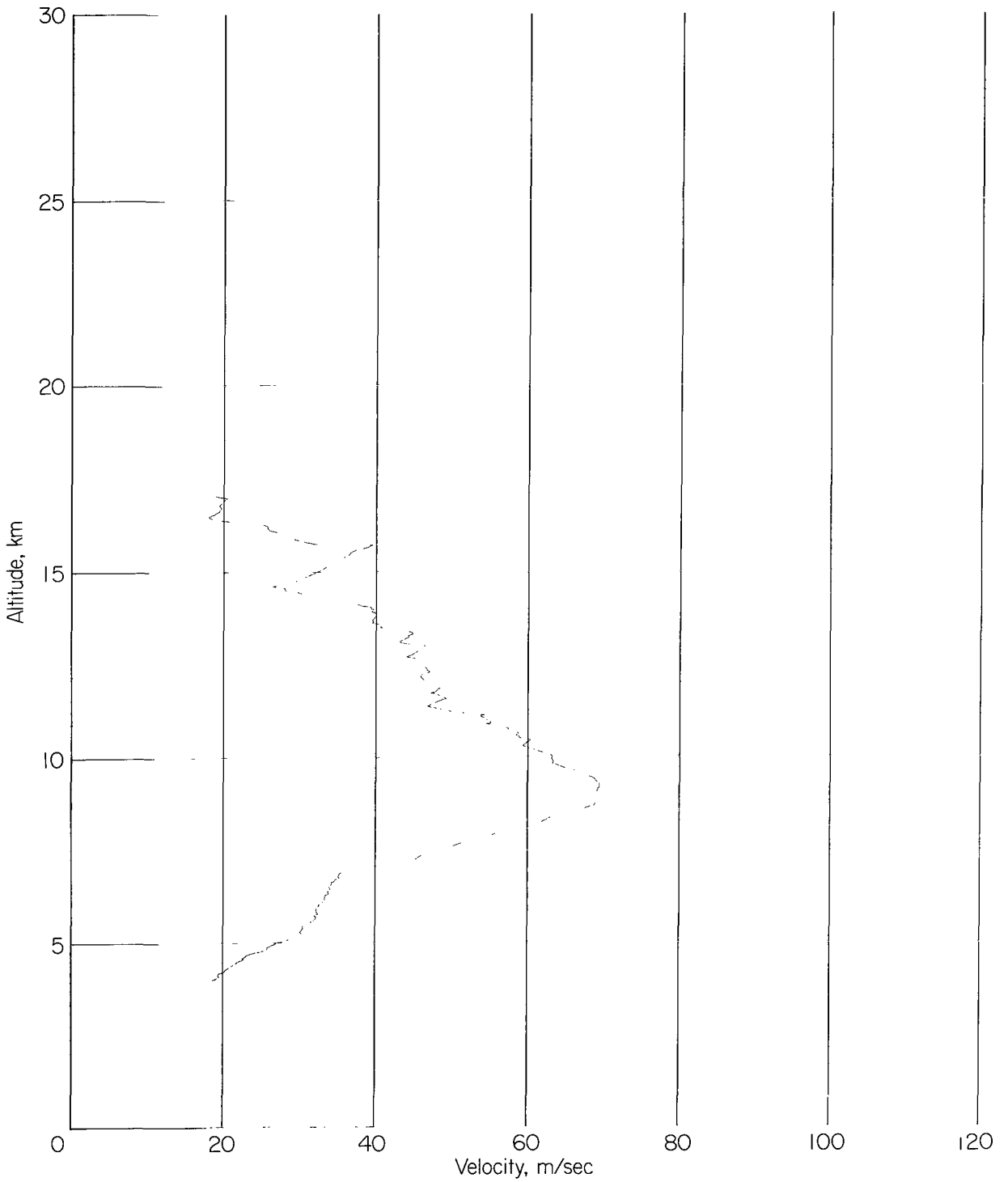
(a) West-to-east velocity component.

Figure 4.- Wind profile of smoke trail 029 obtained April 25, 1963. Time interval, 60 seconds; height interval, 25 meters.



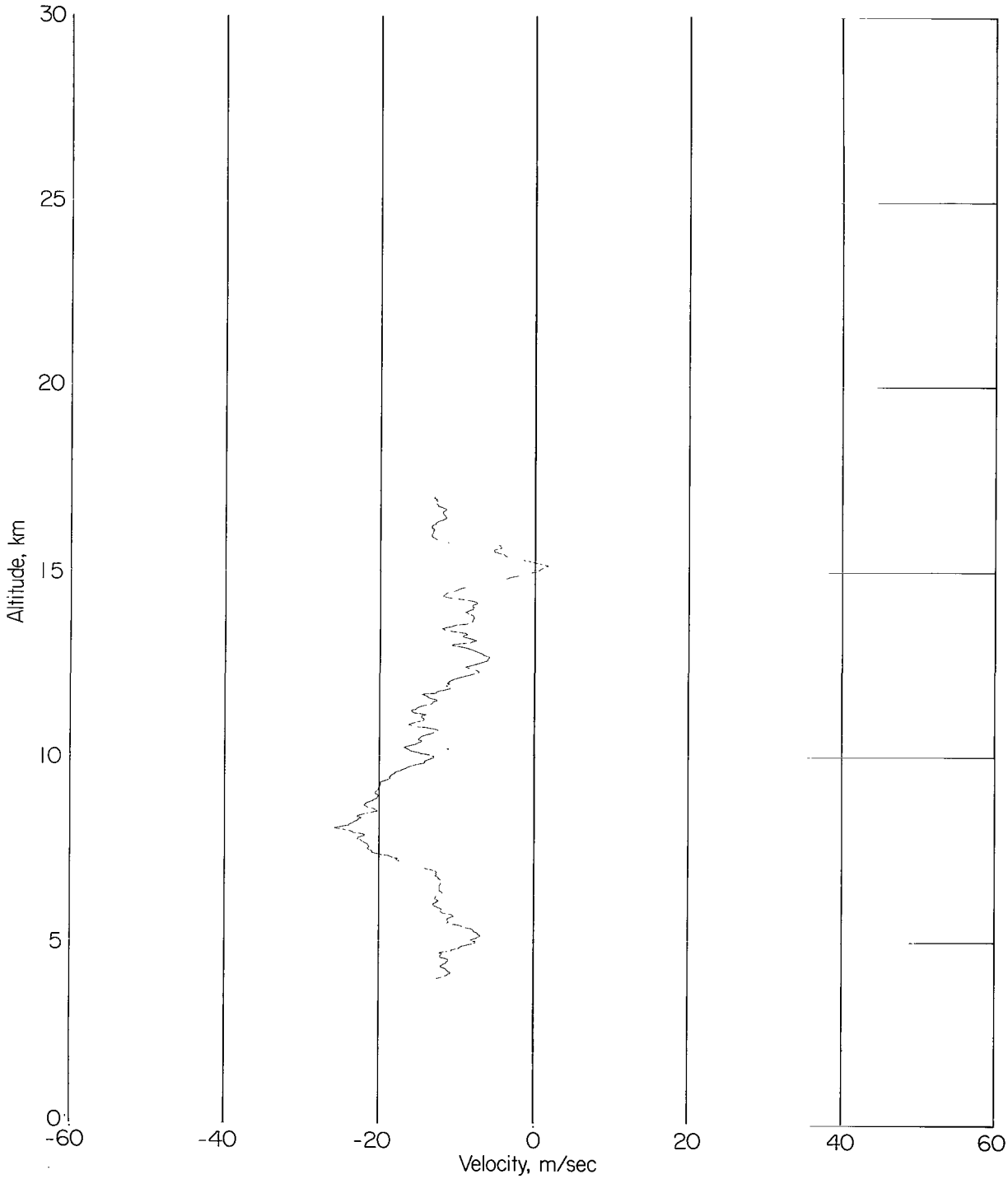
(b) South-to-north velocity component.

Figure 4.- Concluded.



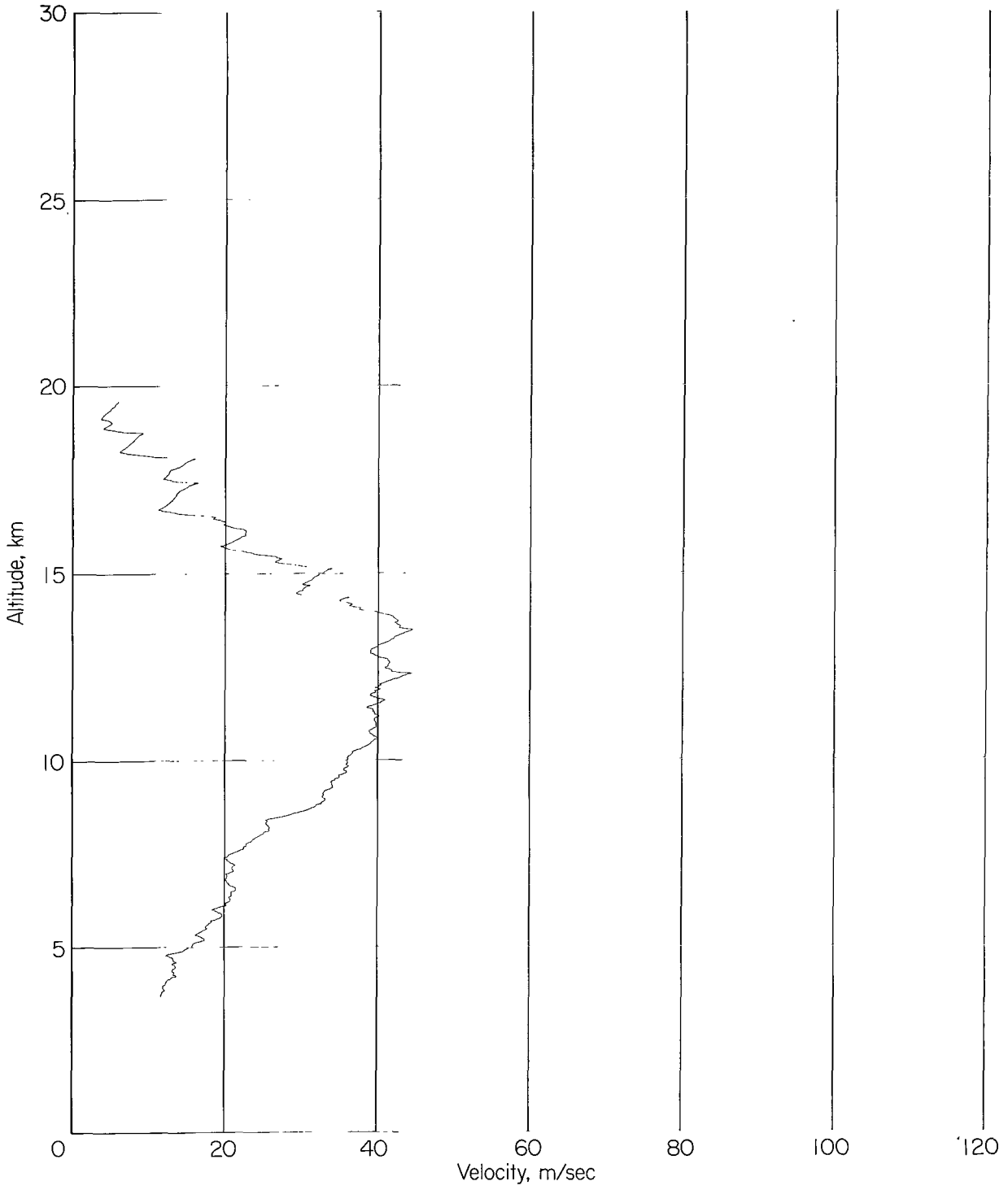
(a) West-to-east velocity component.

Figure 5.- Wind profile of smoke trail 030 obtained April 25, 1963. Time interval, 60 seconds; height interval, 25 meters.



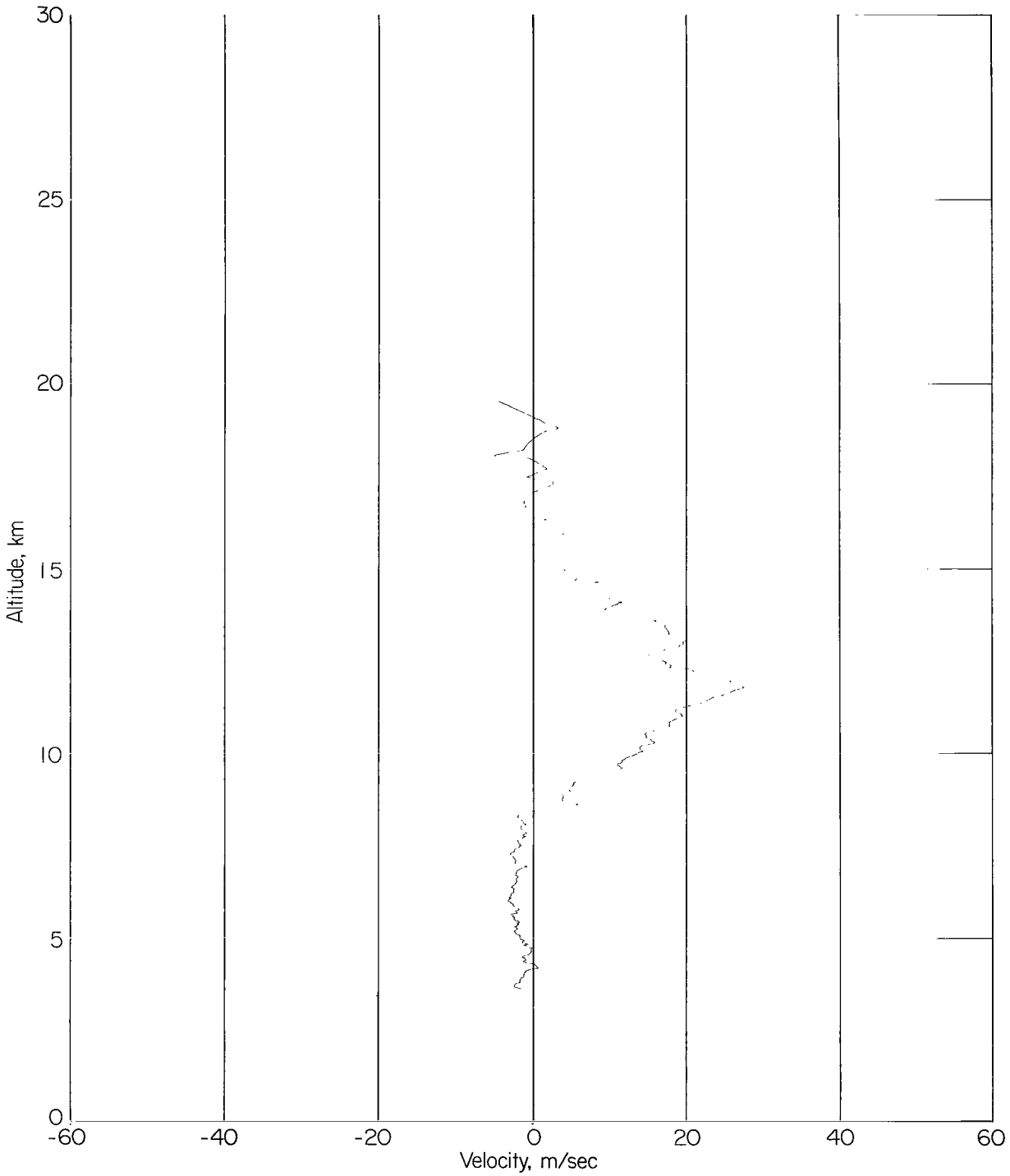
(b) South-to-north velocity component.

Figure 5.- Concluded.



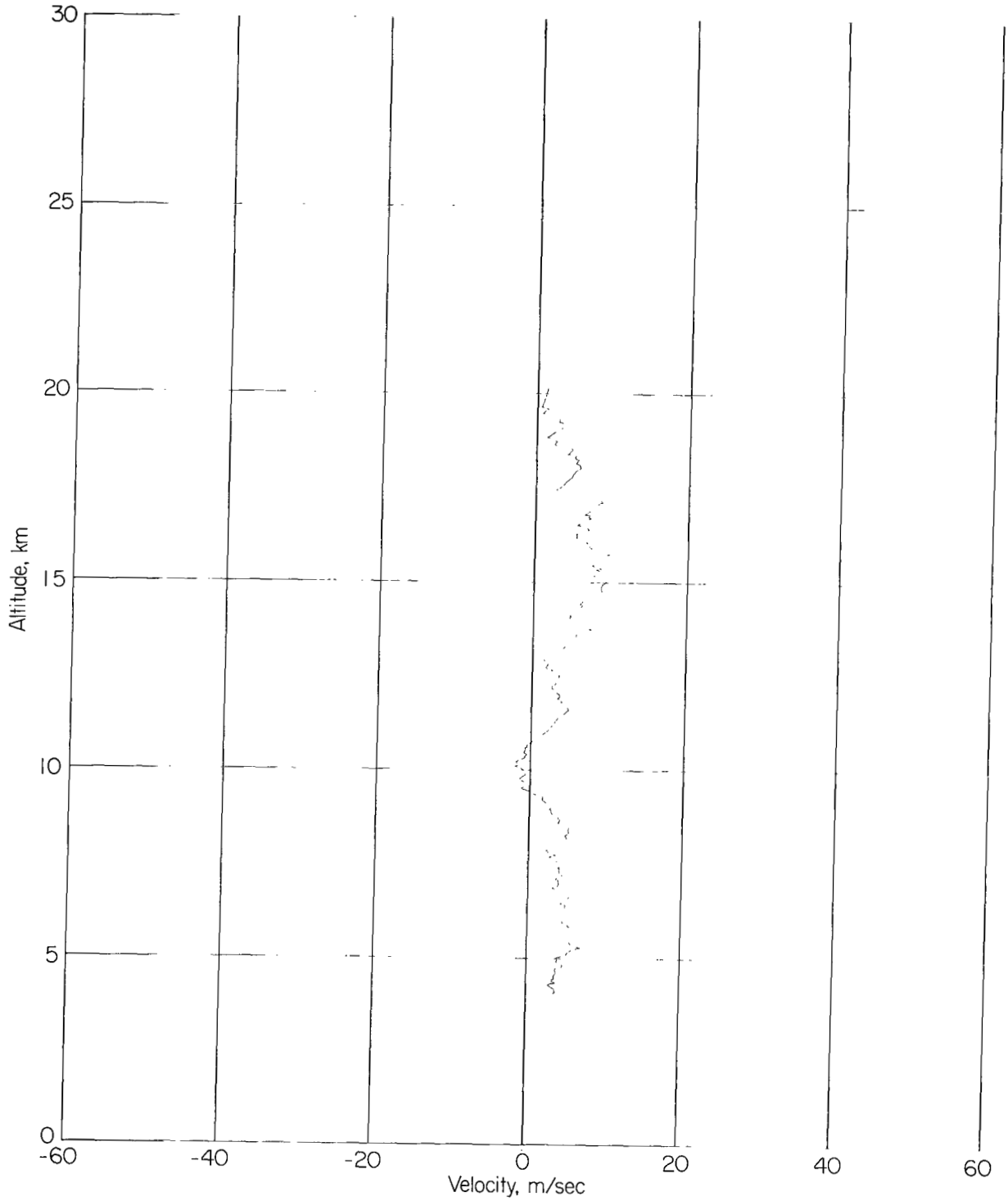
(a) West-to-east velocity component.

Figure 6.- Wind profile of smoke trail 031 obtained August 15, 1963. Time interval, 60 seconds; height interval, 25 meters.



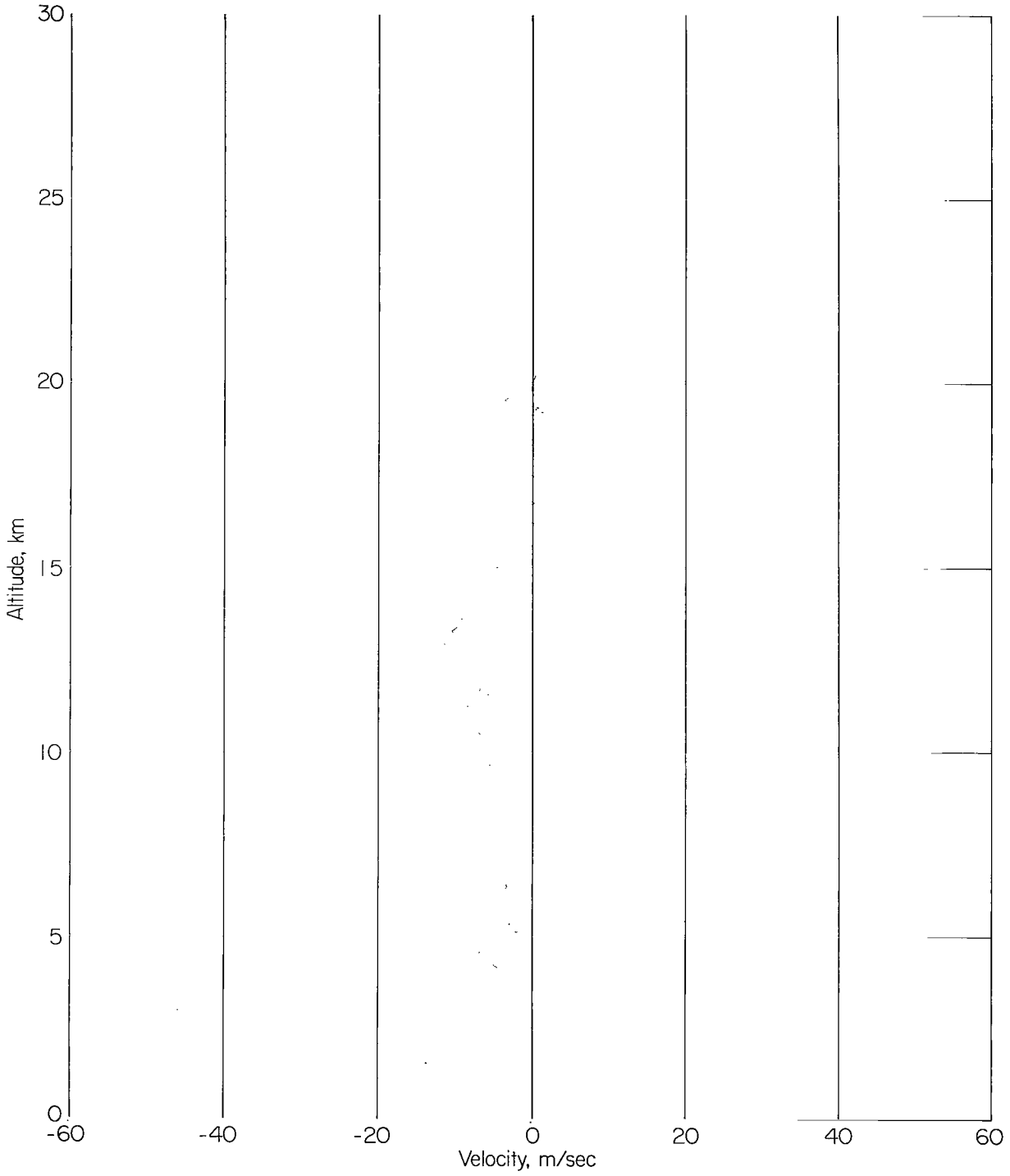
(b) South-to-north velocity component.

Figure 6.- Concluded.



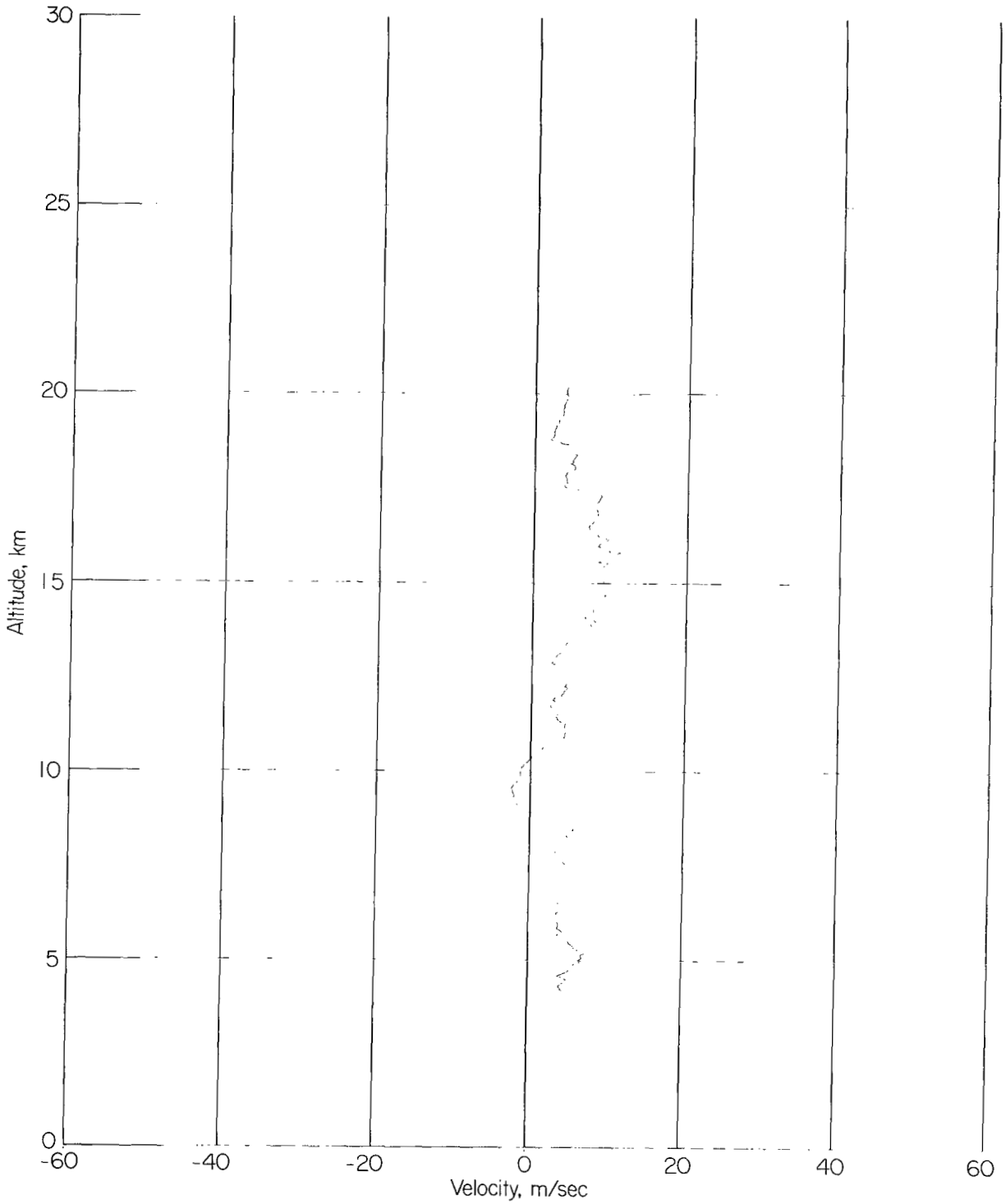
(a) West-to-east velocity component.

Figure 7.- Wind profile of smoke trail 032 obtained September 19, 1963. Time interval, 60 seconds; height interval, 25 meters.



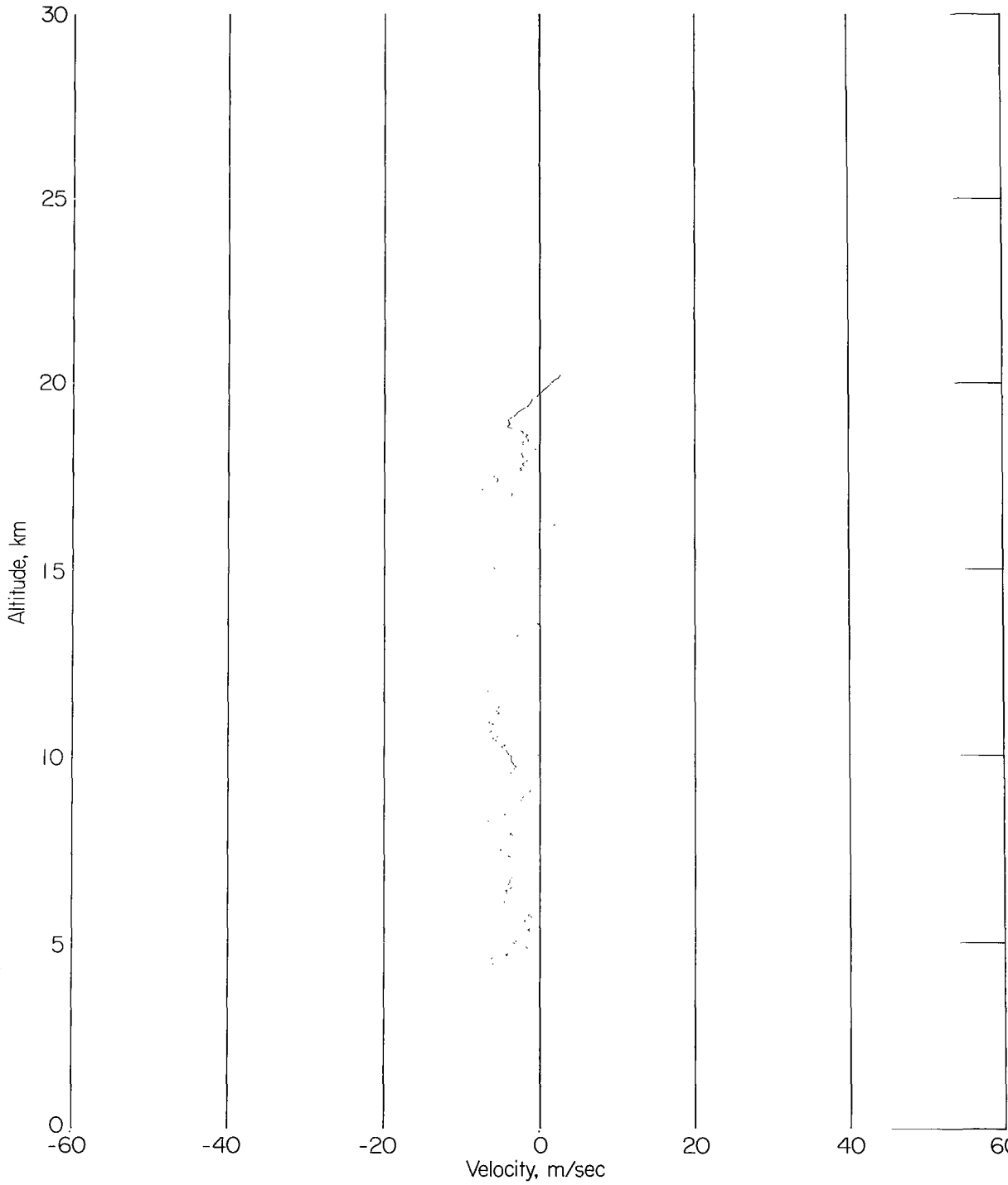
(b) South-to-north velocity component.

Figure 7.- Concluded.



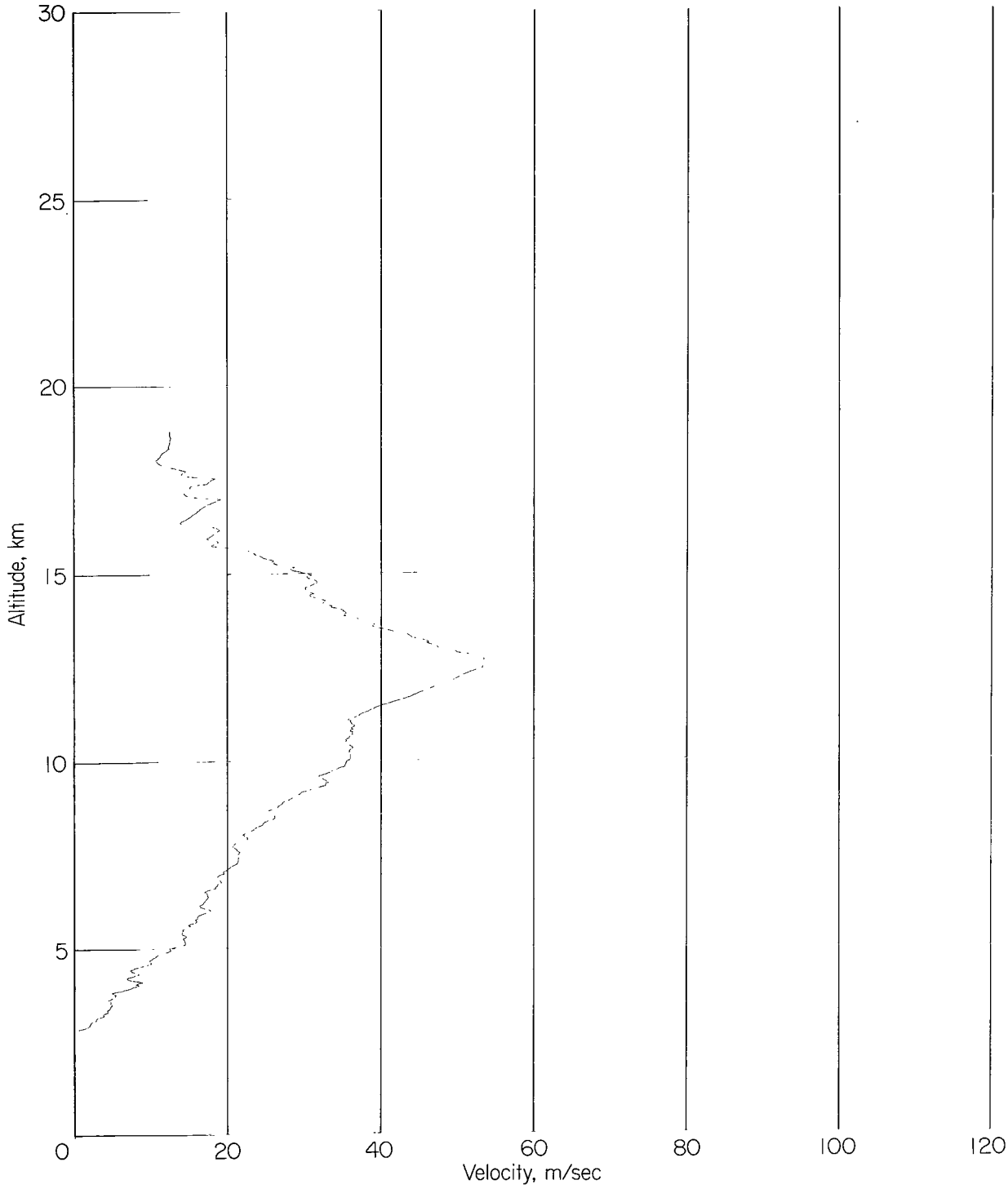
(a) West-to-east velocity component.

Figure 8.- Wind profile of smoke trail 033 obtained September 19, 1963. Time interval, 60 seconds; height interval, 25 meters.



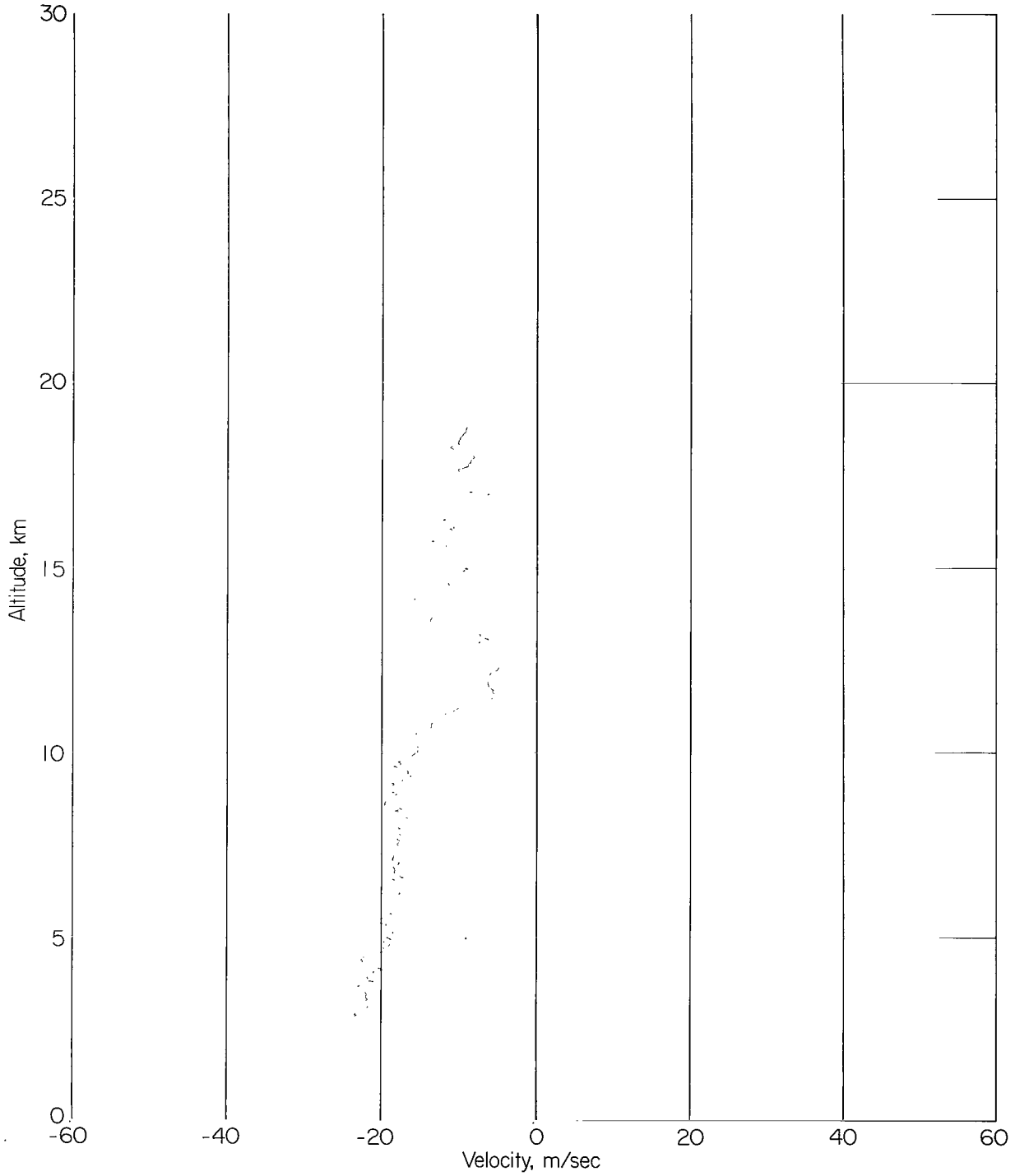
(b) South-to-north velocity component.

Figure 8.- Concluded.



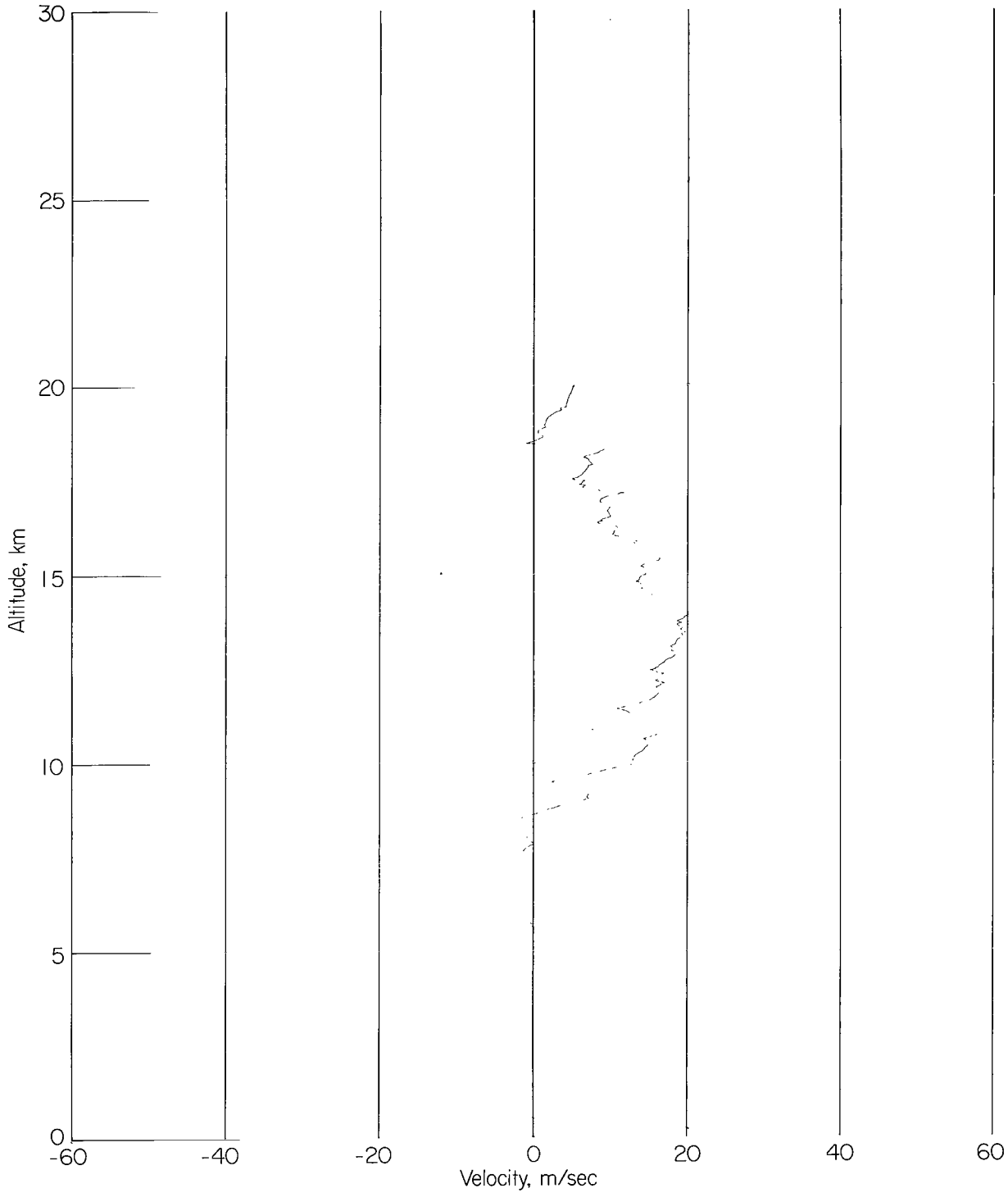
(a) West-to-east velocity component.

Figure 9.- Wind profile of smoke trail 034 obtained September 23, 1963. Time interval, 60 seconds; height interval, 25 meters.



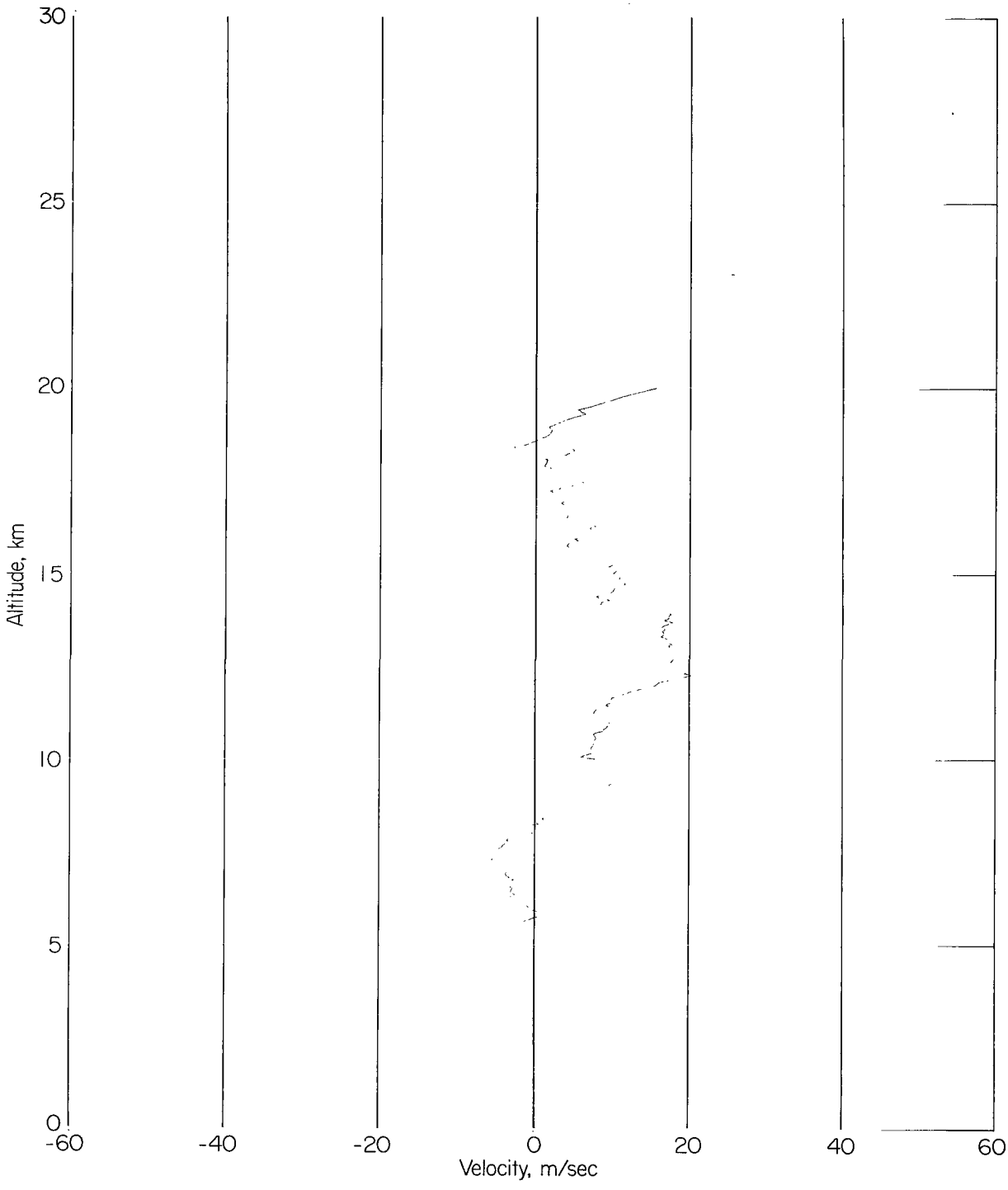
(b) South-to-north velocity component.

Figure 9.- Concluded.



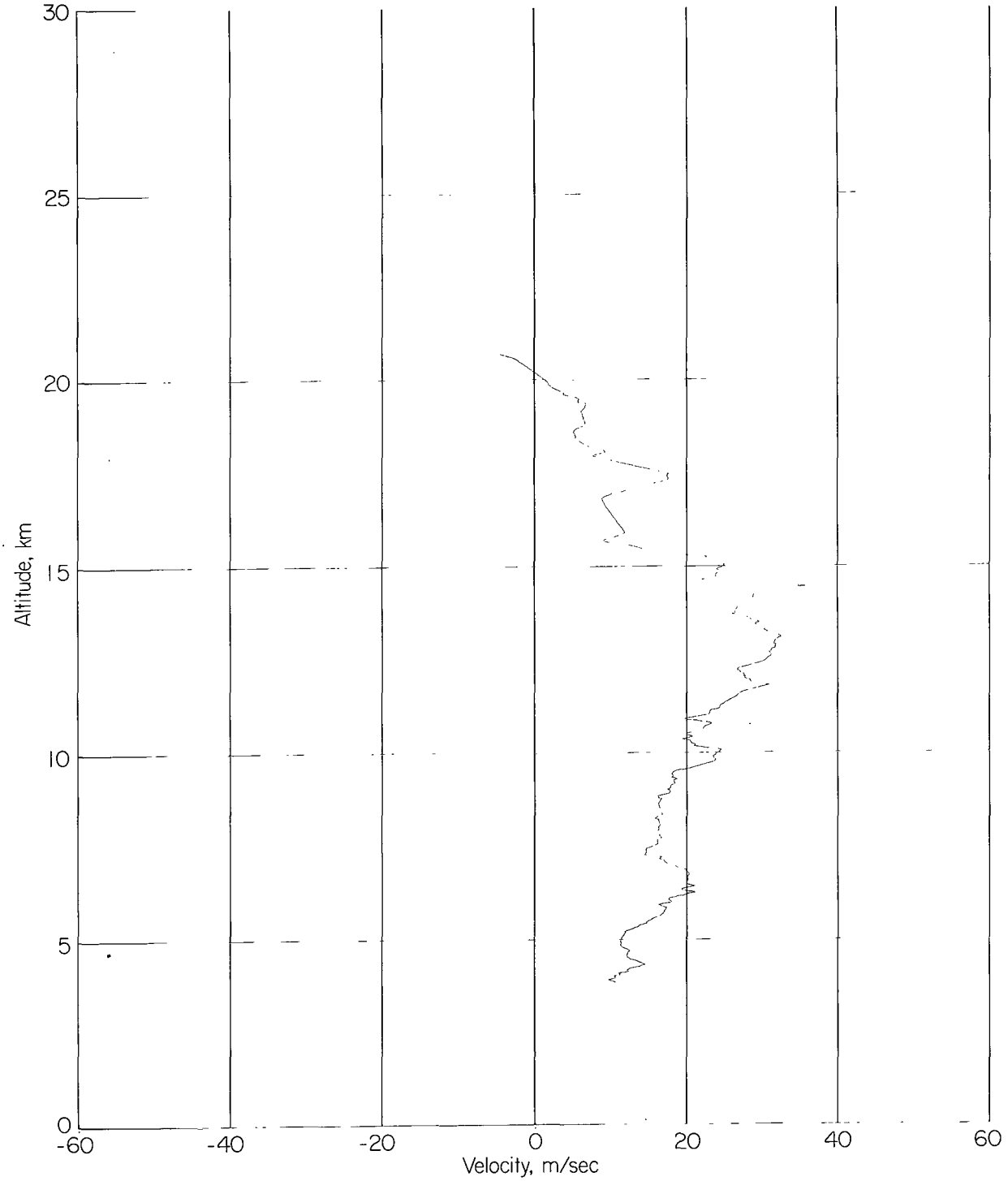
(a) West-to-east velocity component.

Figure 10.- Wind profile of smoke trail 035 obtained October 1, 1963. Time interval, 60 seconds; height interval, 25 meters.



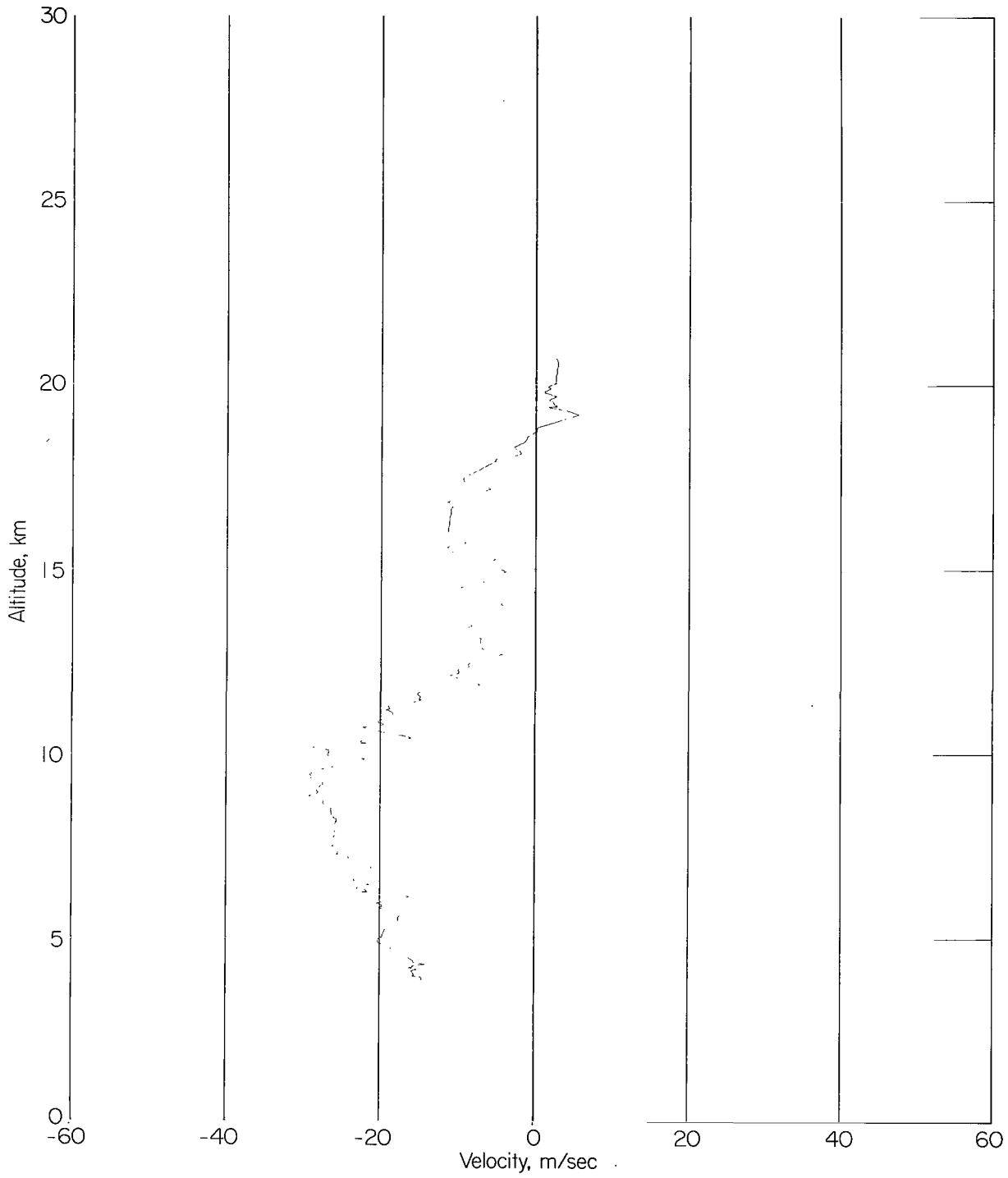
(b) South-to-north velocity component.

Figure 10.- Concluded.



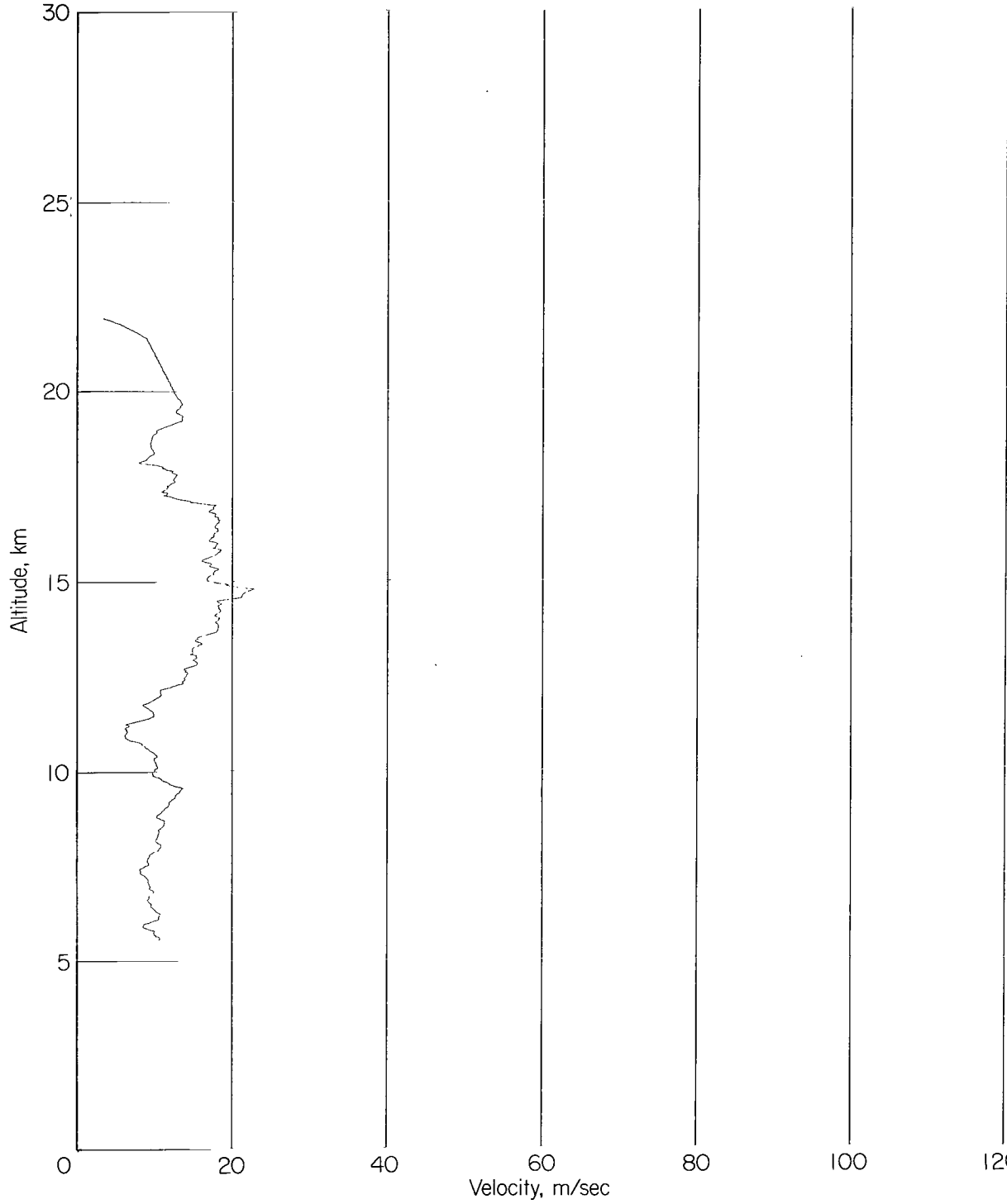
(a) West-to-east velocity component.

Figure 11.- Wind profile of smoke trail 036 obtained October 4, 1963. Time interval, 60 seconds; height interval, 25 meters.



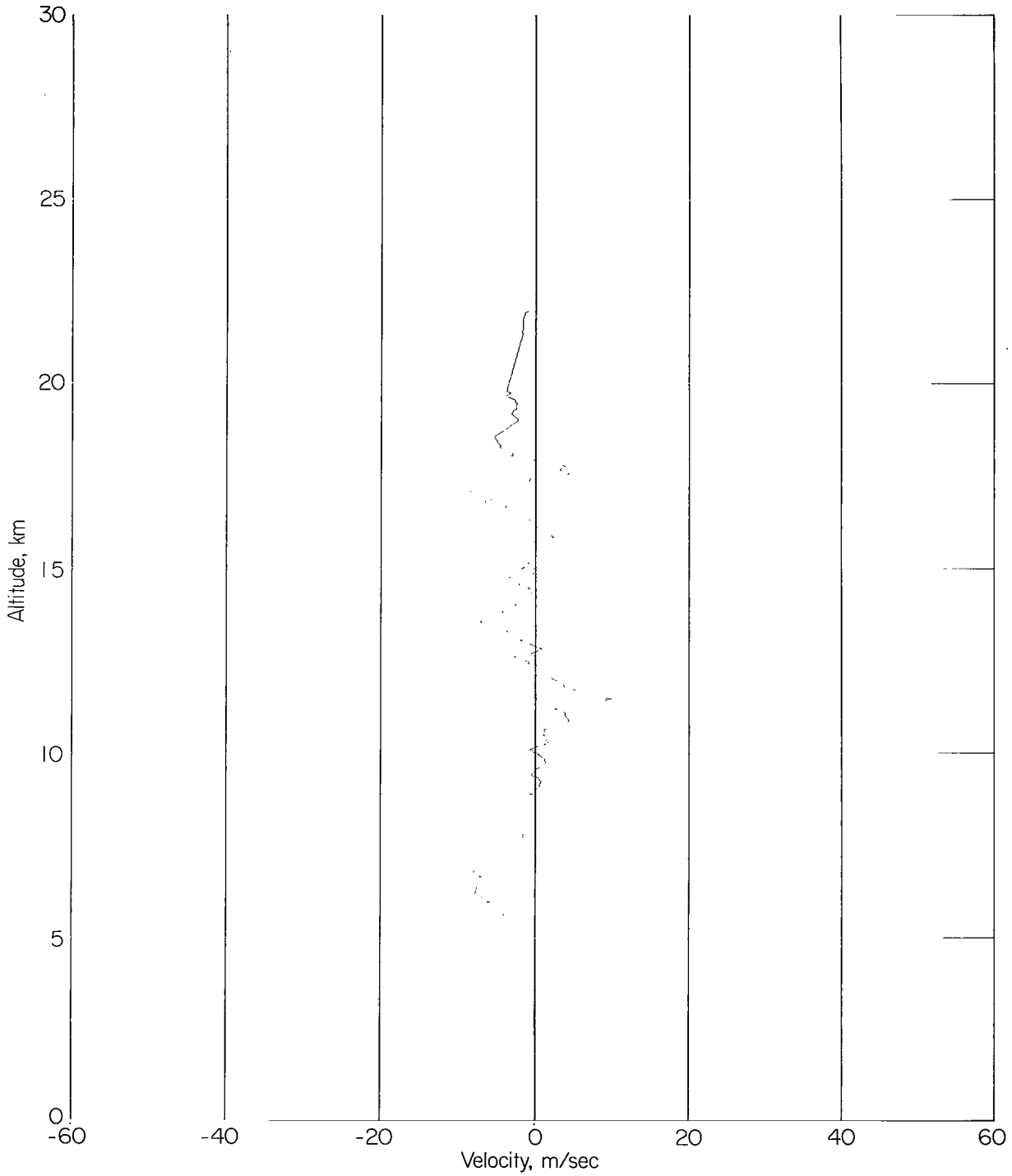
(b) South-to-north velocity component.

Figure 11.- Concluded.



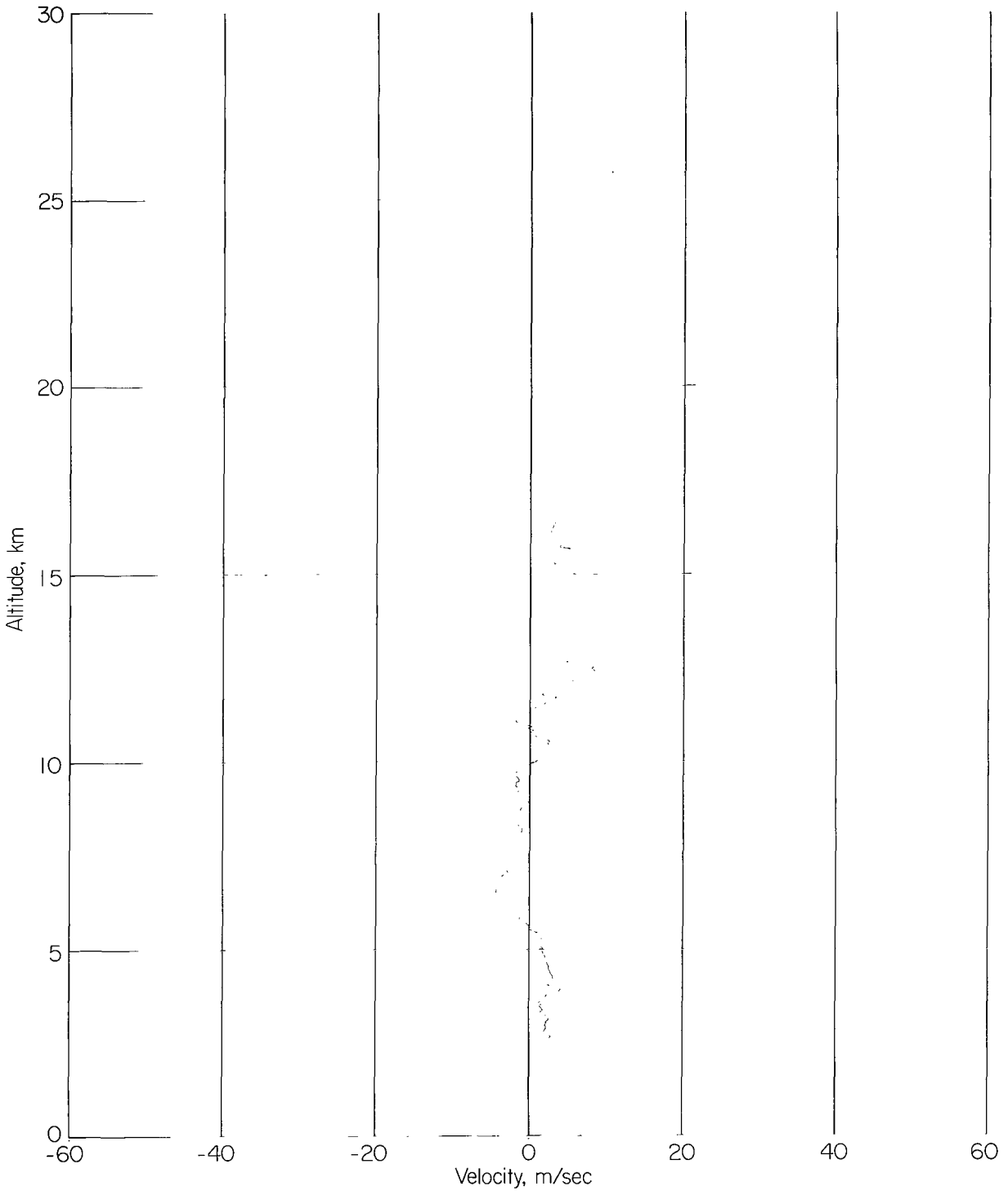
(a) West-to-east velocity component.

Figure 12.- Wind profile of smoke trail 037 obtained October 11, 1963. Time interval, 60 seconds; height interval, 25 meters.



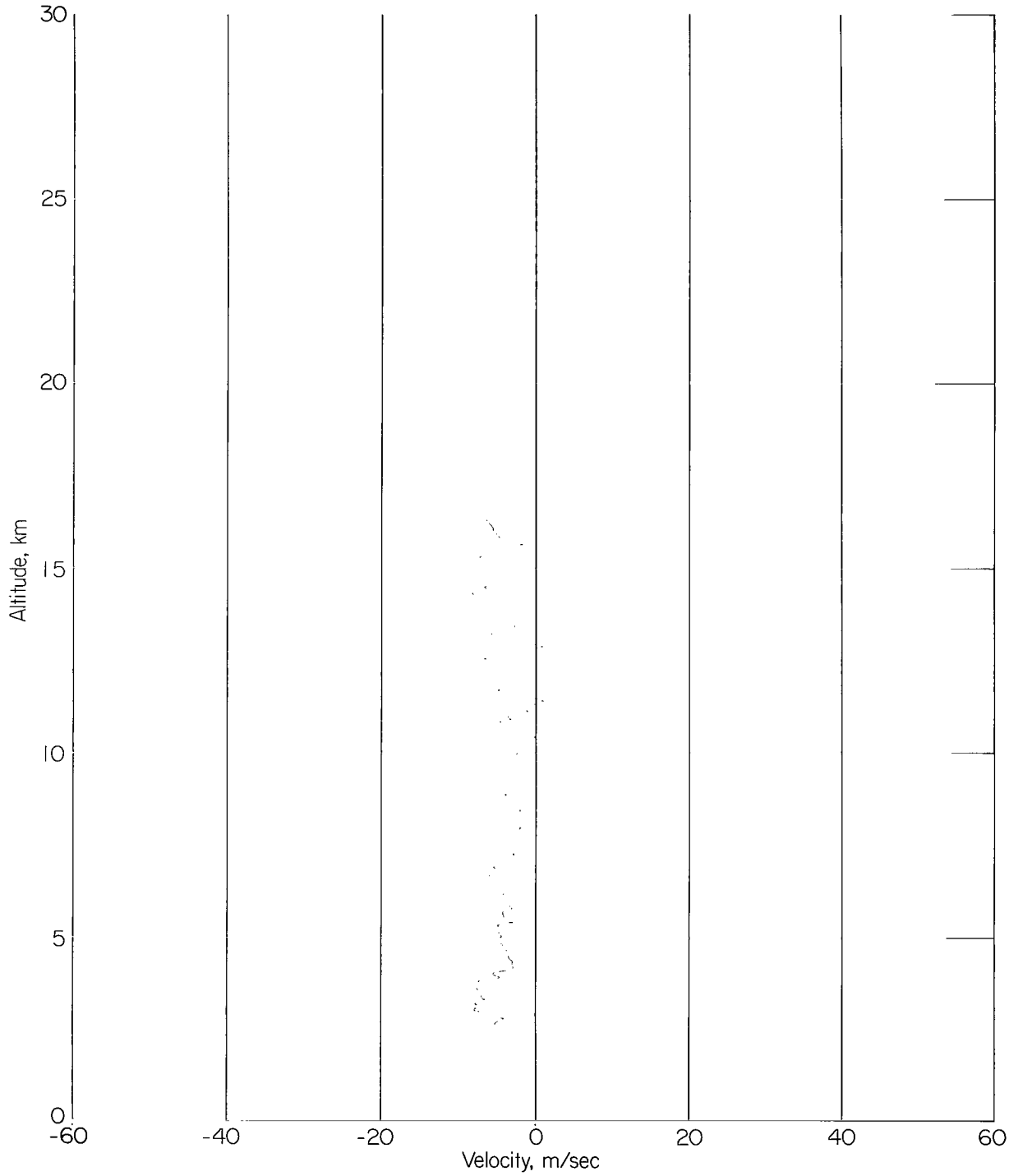
(b) South-to-north velocity component.

Figure 12.- Concluded.



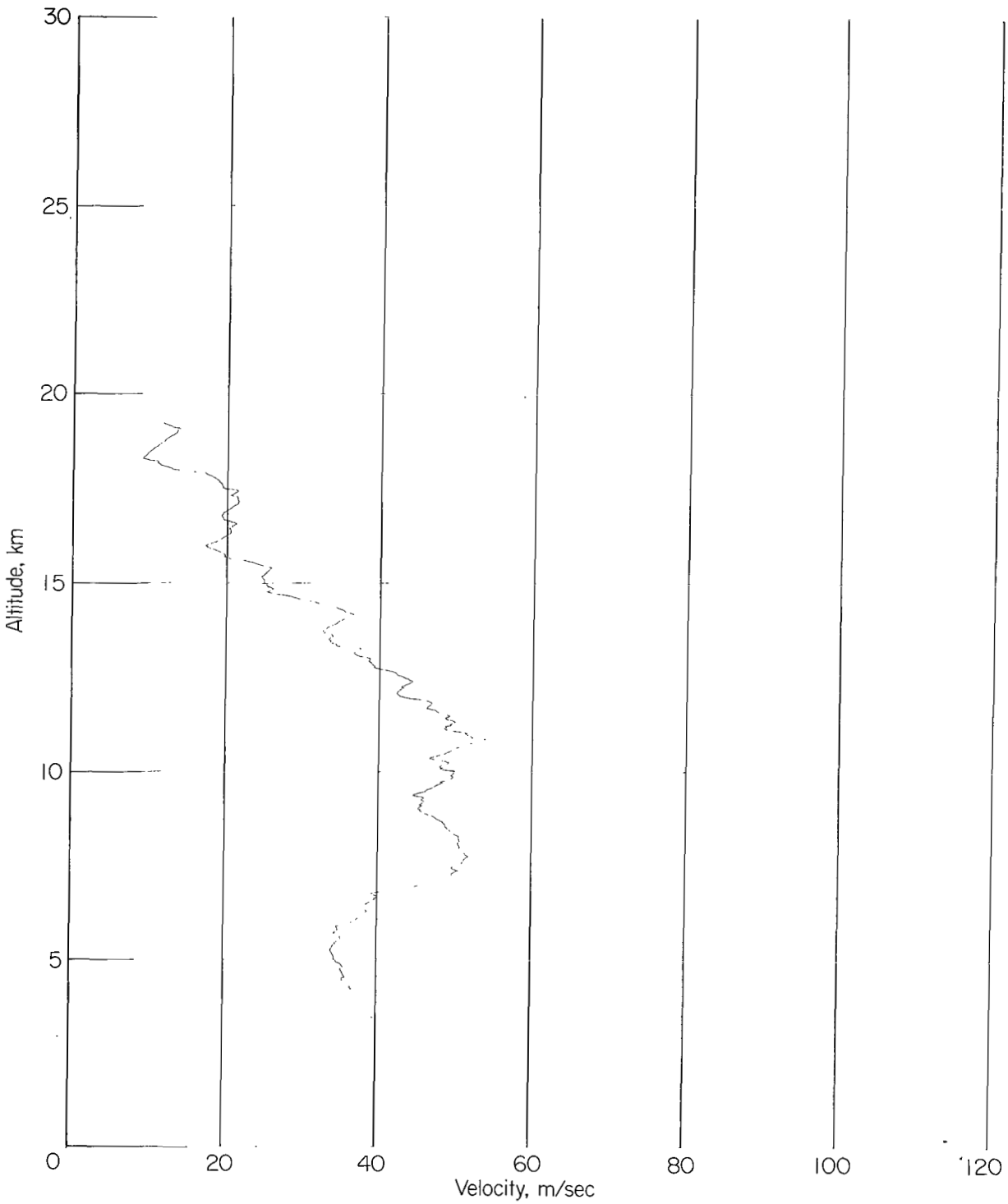
(a) West-to-east velocity component.

Figure 13.- Wind profile of smoke trail 038 obtained October 15, 1963. Time interval, 60 seconds; height interval, 25 meters.



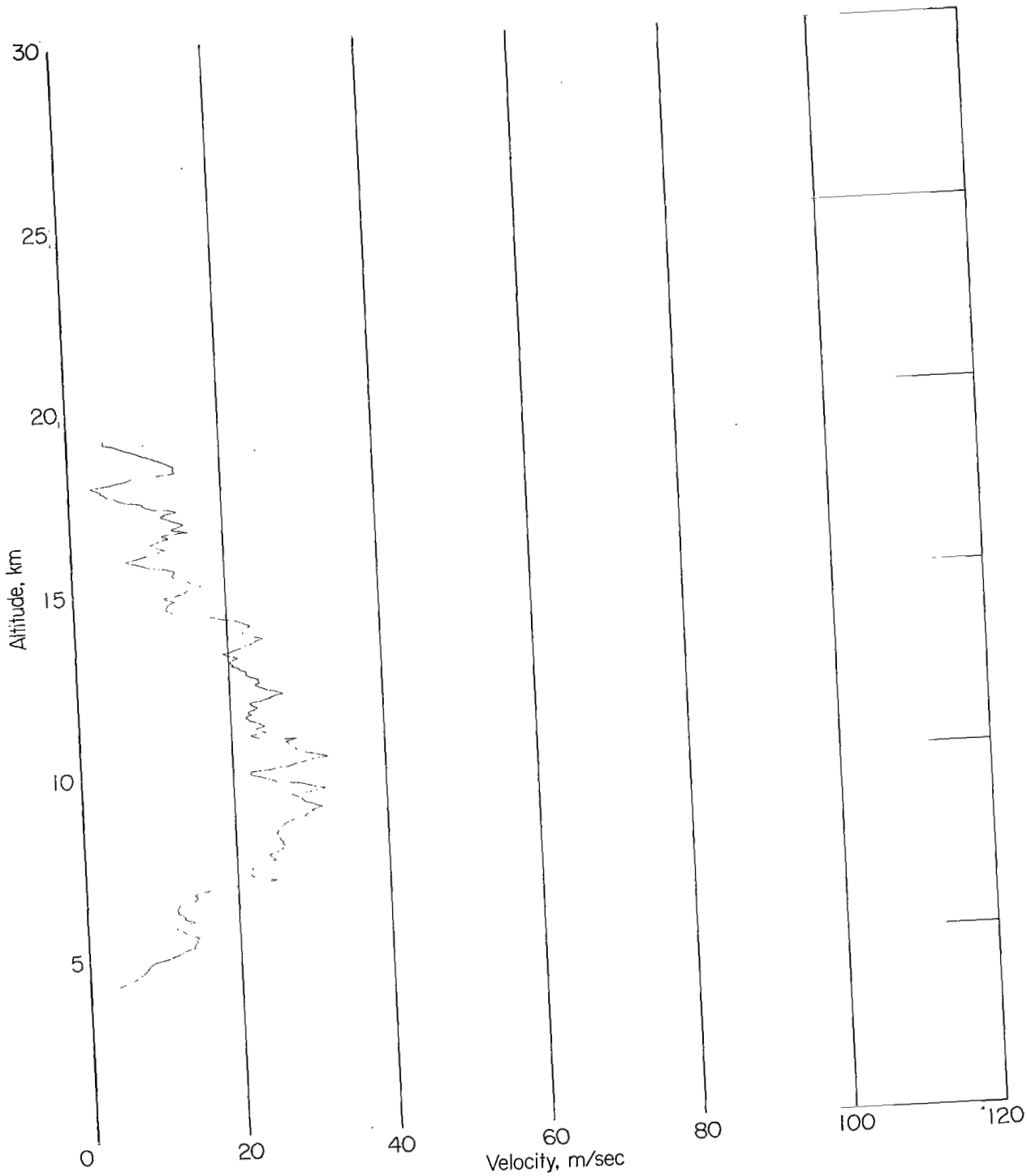
(b) South-to-north velocity component.

Figure 13.- Concluded.



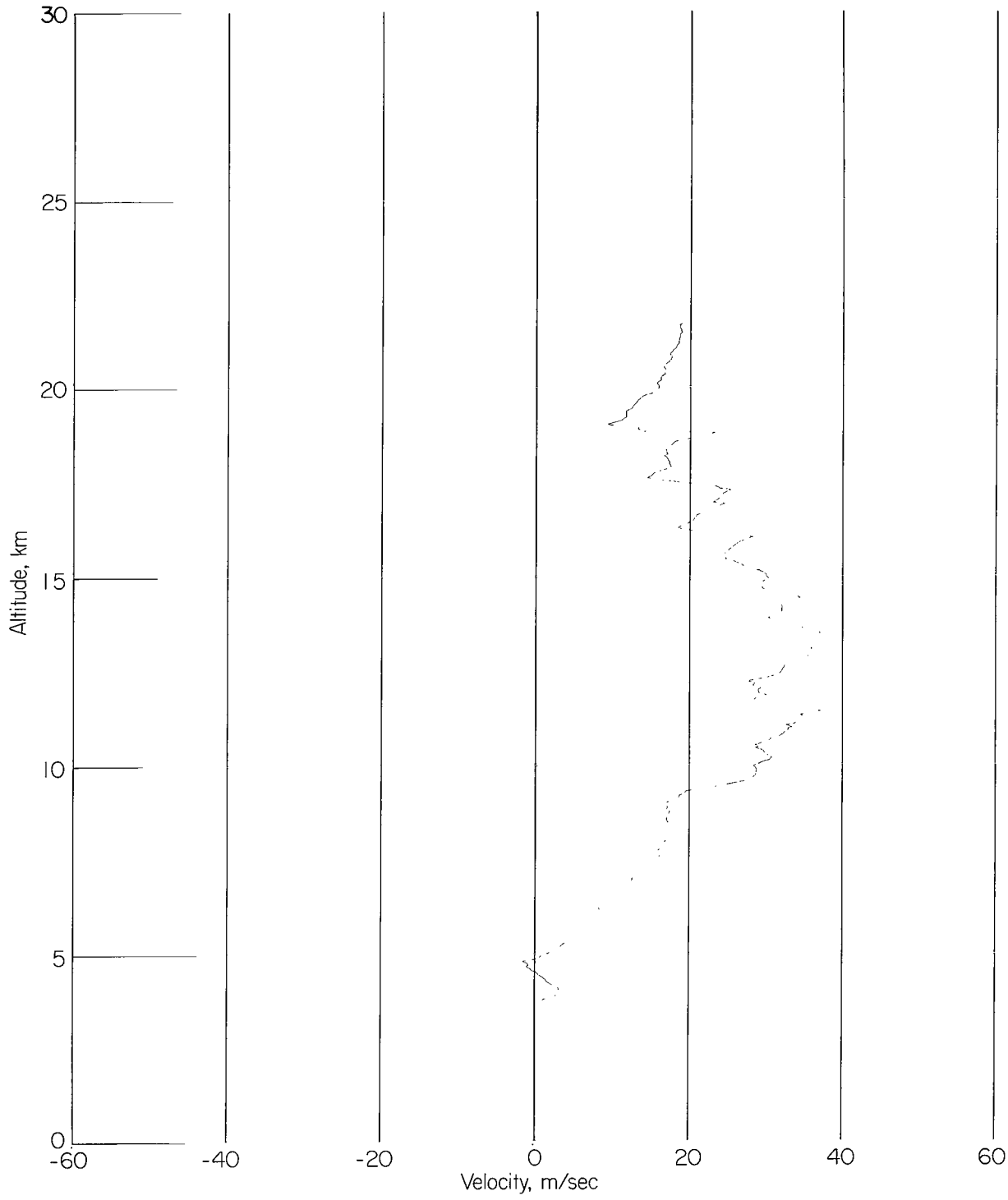
(a) West-to-east velocity component.

Figure 14.- Wind profile of smoke trail 039 obtained November 12, 1963. Time interval, 60 seconds; height interval, 25 meters.



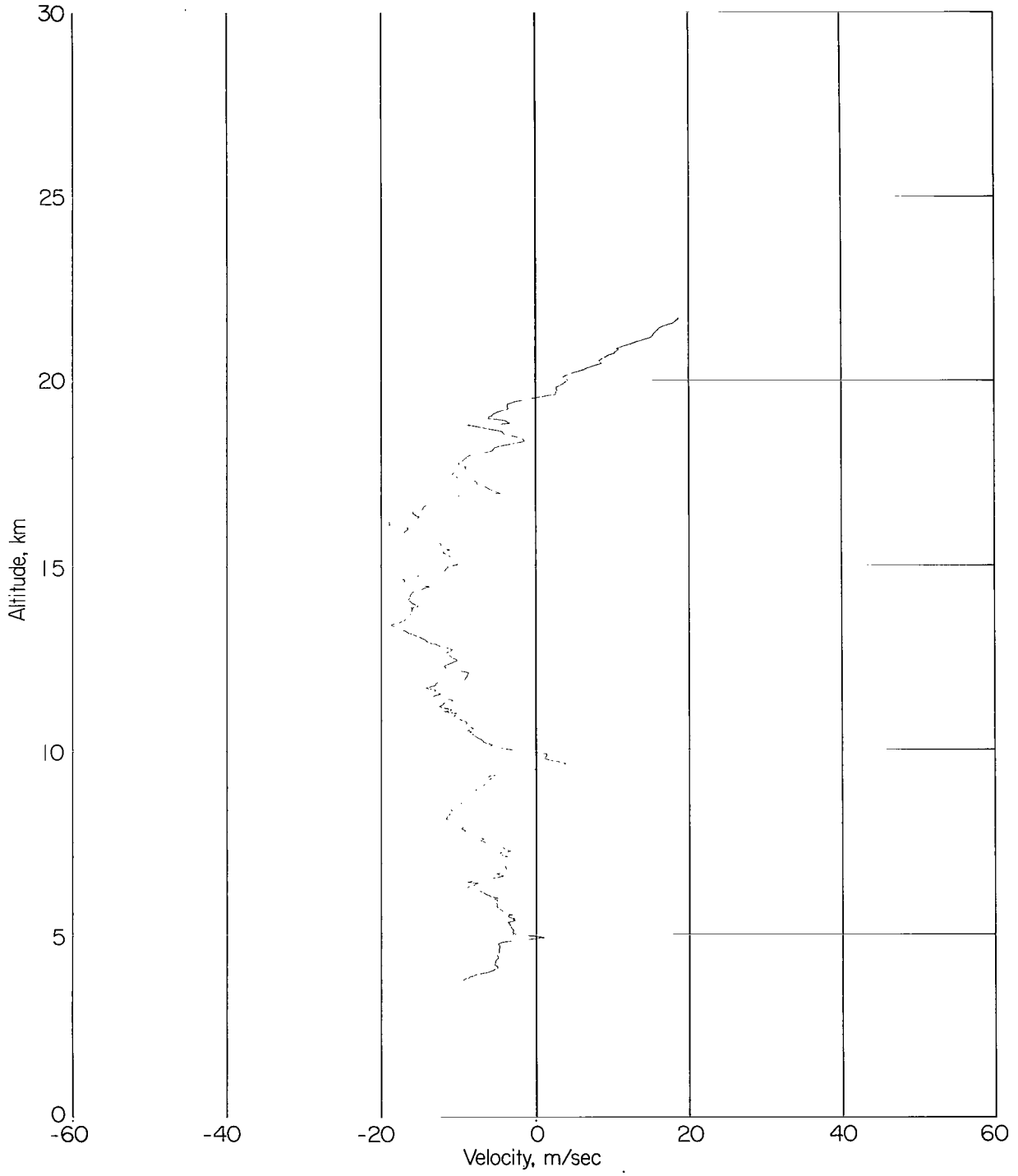
(b) South-to-north velocity component.

Figure 14.- Concluded.



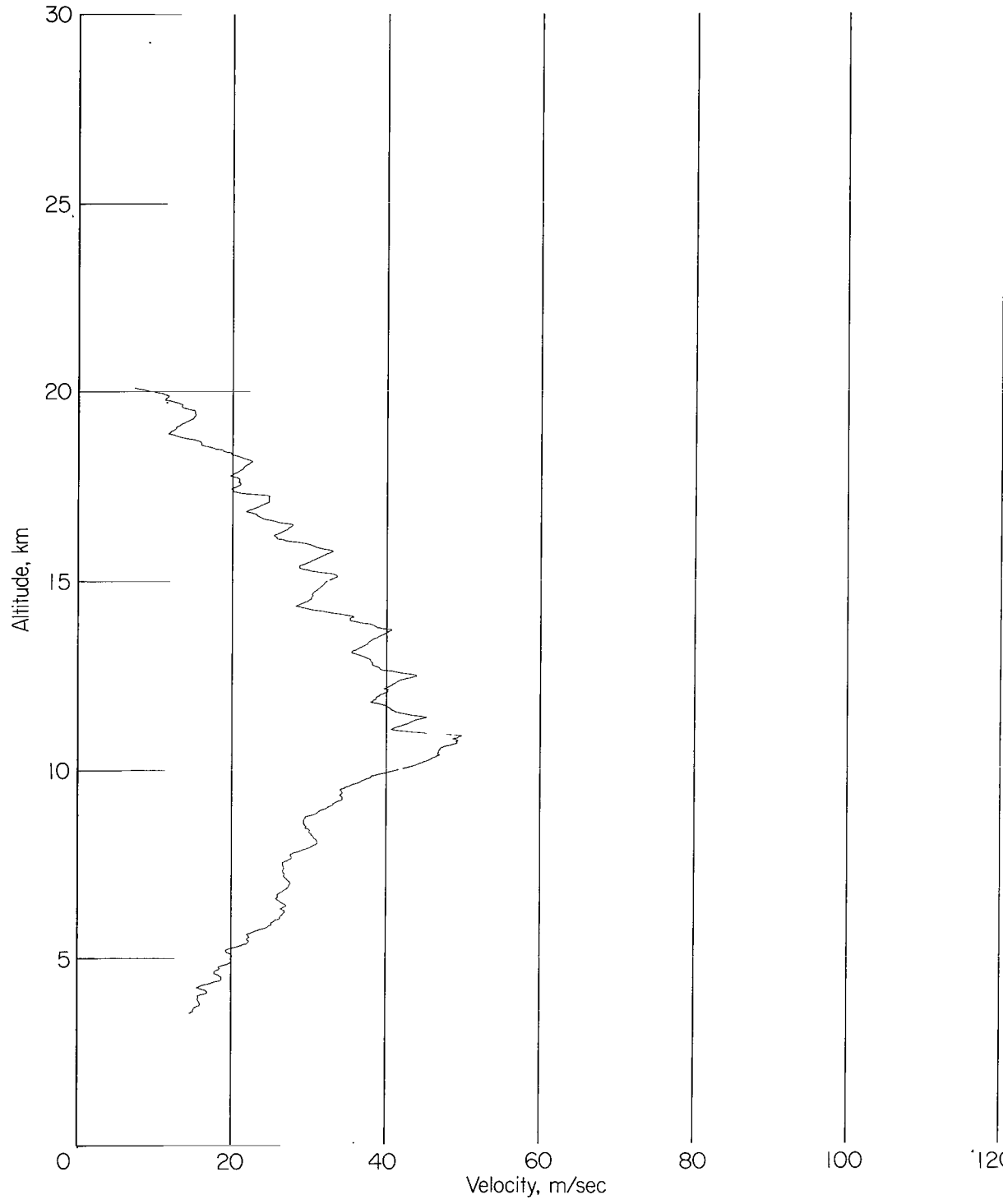
(a) West-to-east velocity component.

Figure 15.- Wind profile of smoke trail 040 obtained January 22, 1964. Time interval, 60 seconds; height interval, 25 meters.



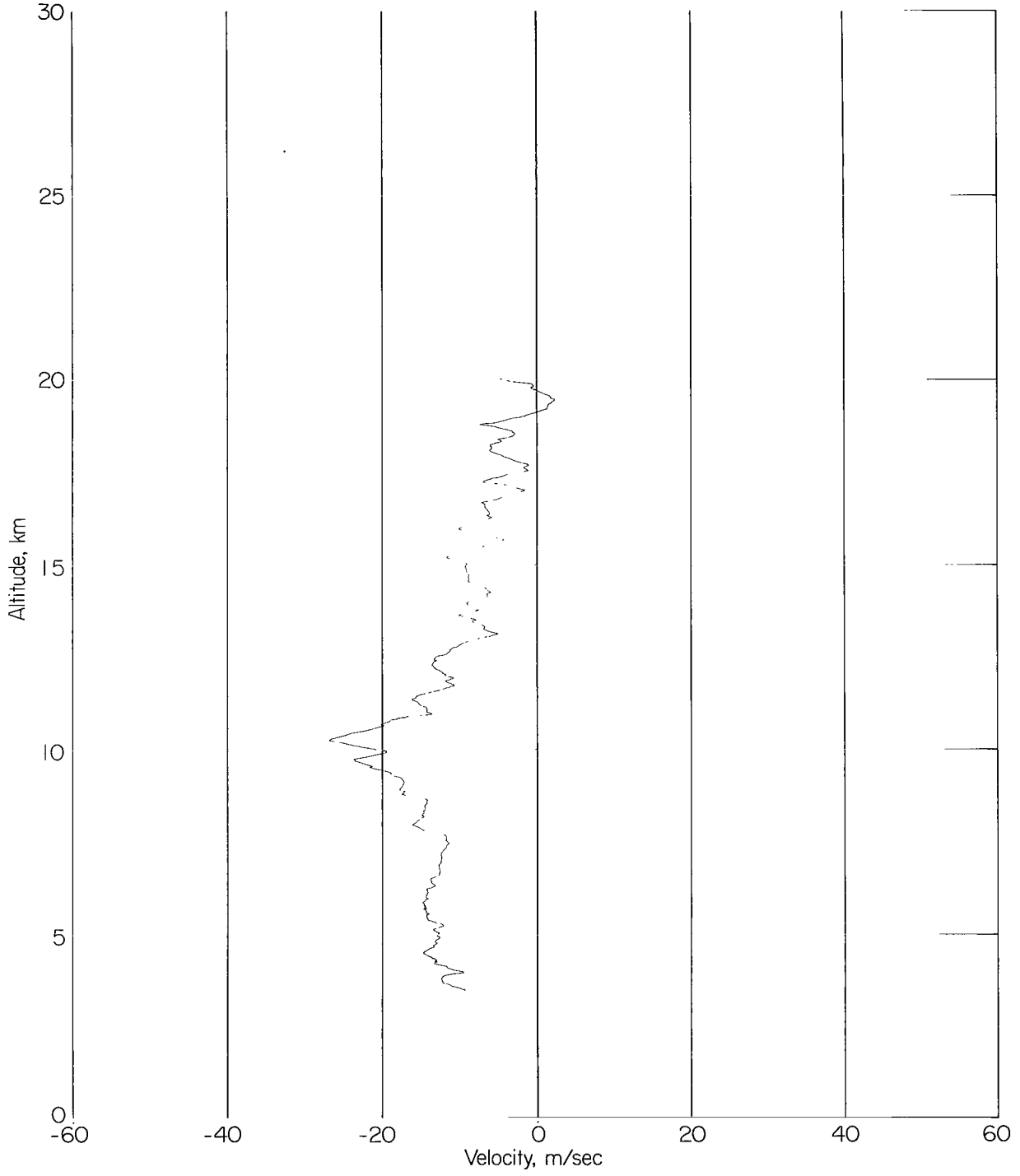
(b) South-to-north velocity component.

Figure 15.- Concluded.



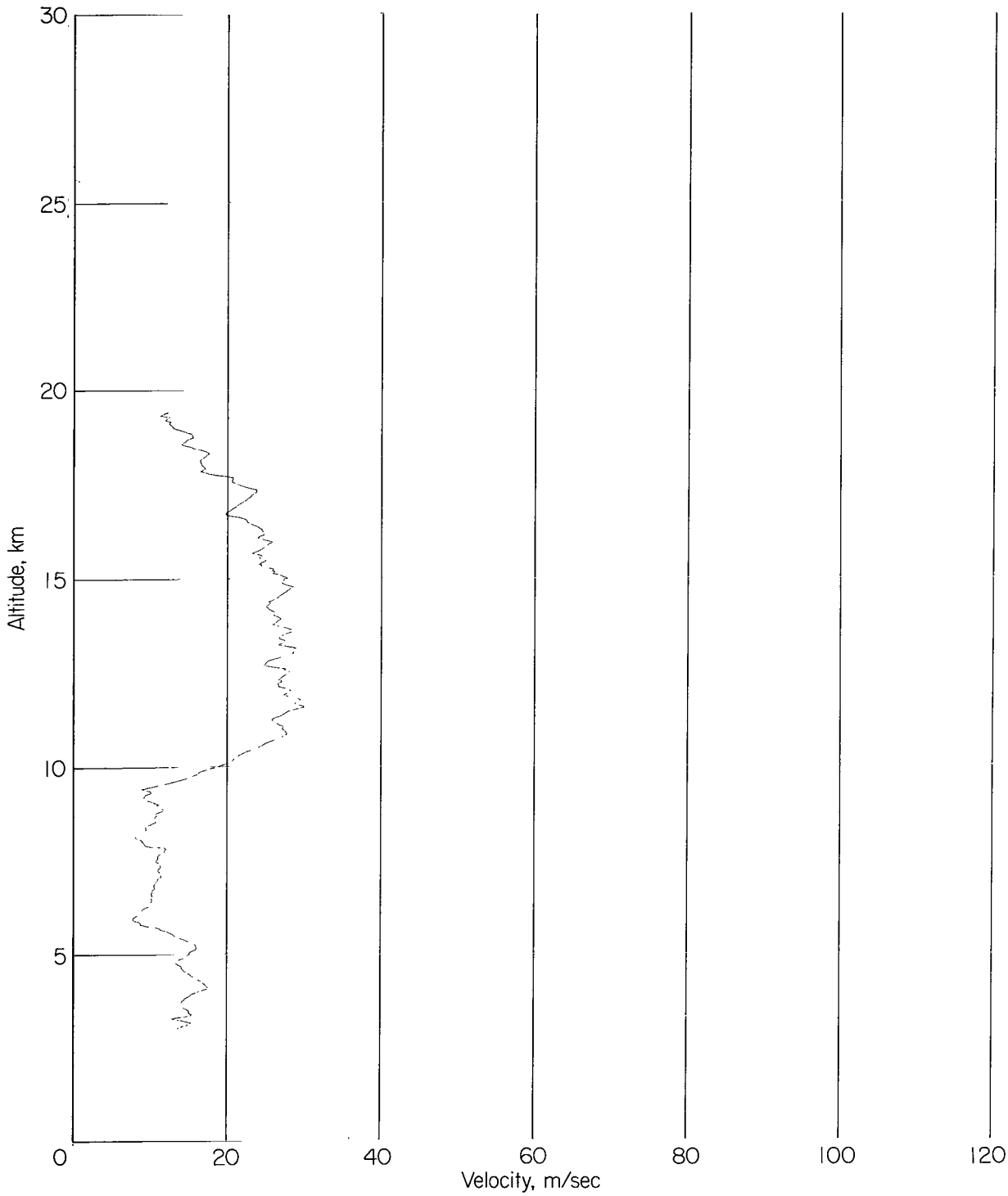
(a) West-to-east velocity component.

Figure 16.- Wind profile of smoke trail 041 obtained January 29, 1964. Time interval, 60 seconds; height interval, 25 meters.



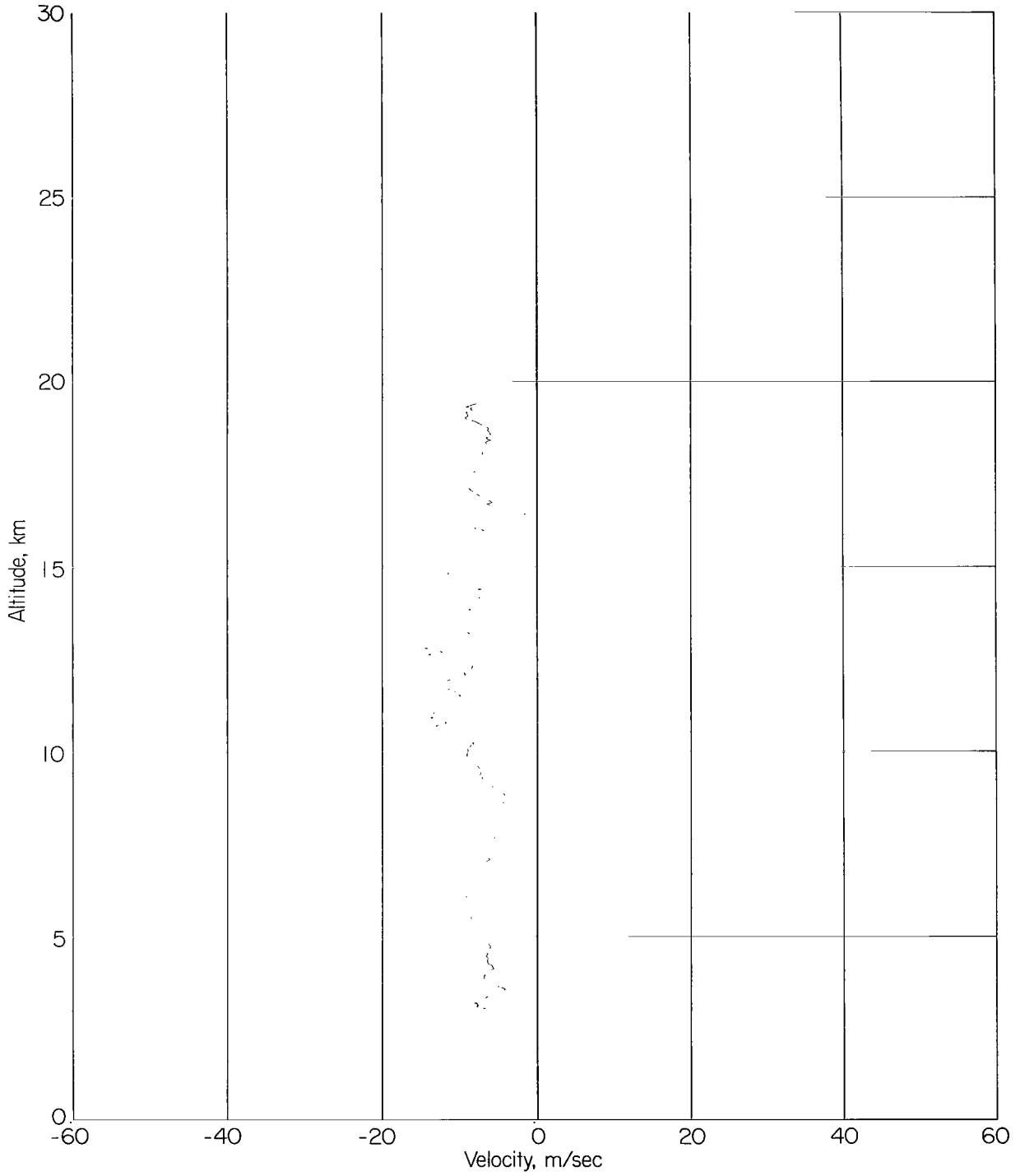
(b) South-to-north velocity component.

Figure 16.- Concluded.



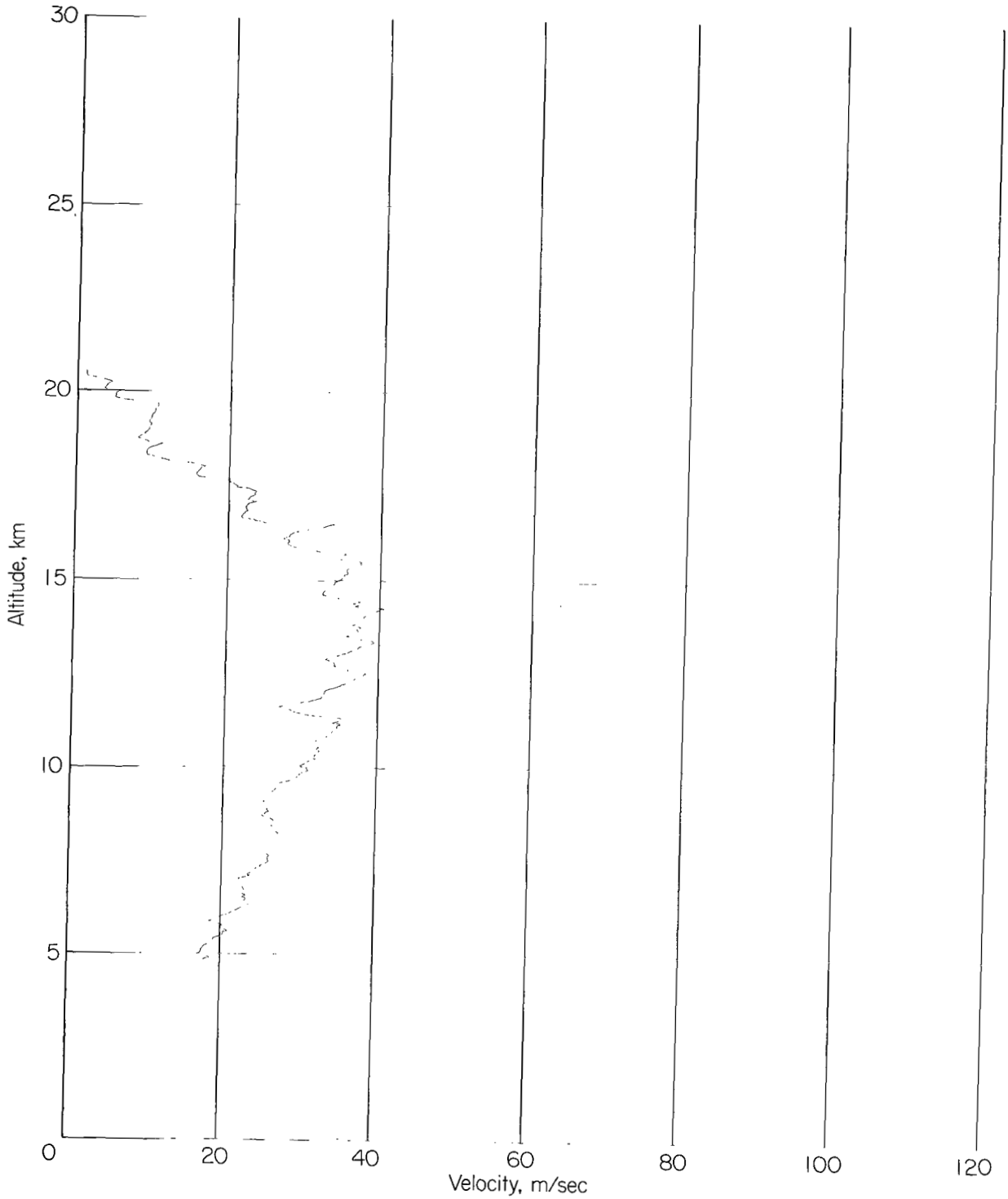
(a) West-to-east velocity component.

Figure 17. Wind profile of smoke trail 042 obtained February 4, 1964. Time interval, 60 seconds; height interval, 25 meters.



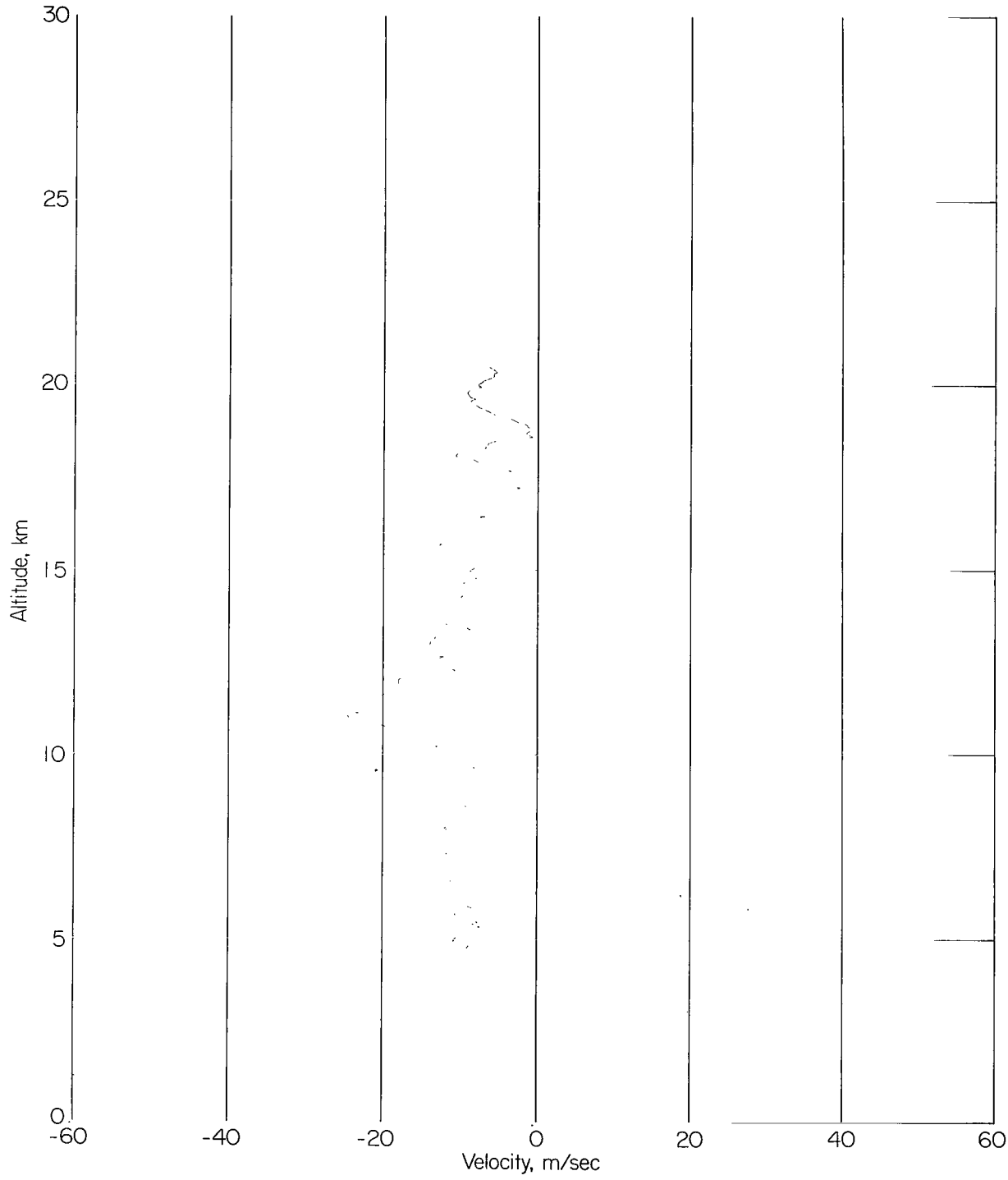
(b) South-to-north velocity component.

Figure 17.- Concluded.



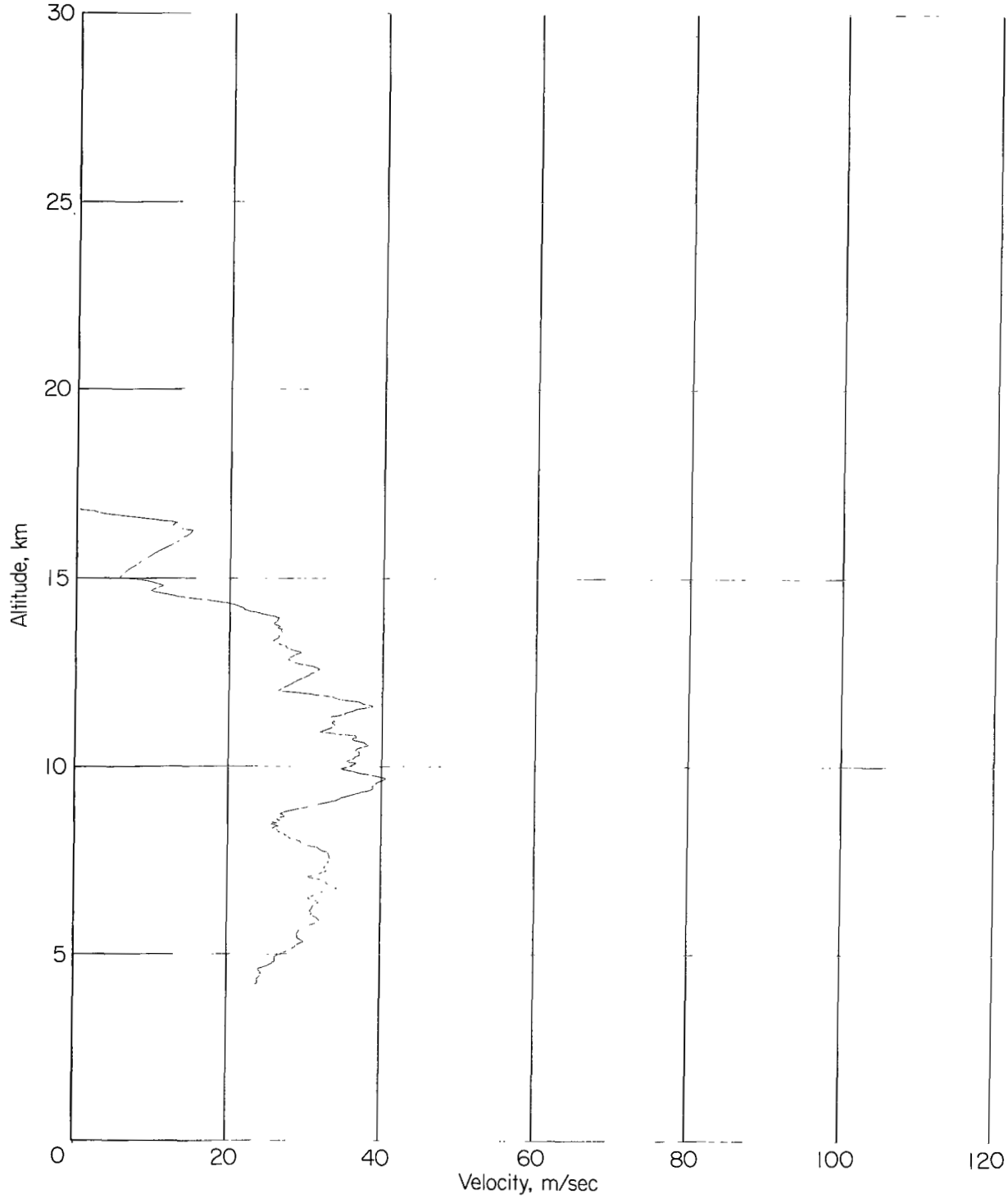
(a) West-to-east velocity component.

Figure 18.- Wind profile of smoke trail 043 obtained March 13, 1964. Time interval, 60 seconds; height interval, 25 meters.



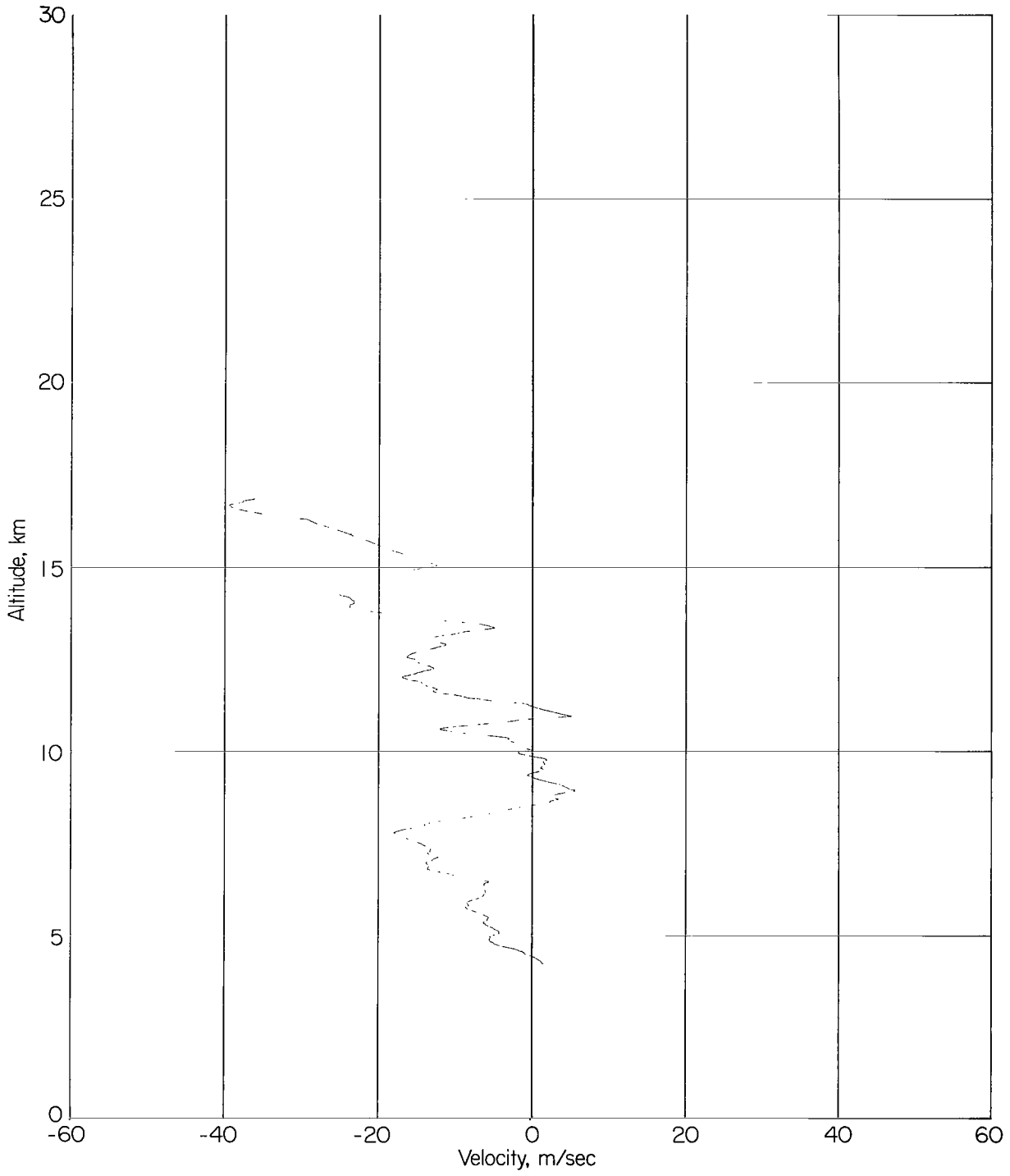
(b) South-to-north velocity component.

Figure 18.- Concluded.



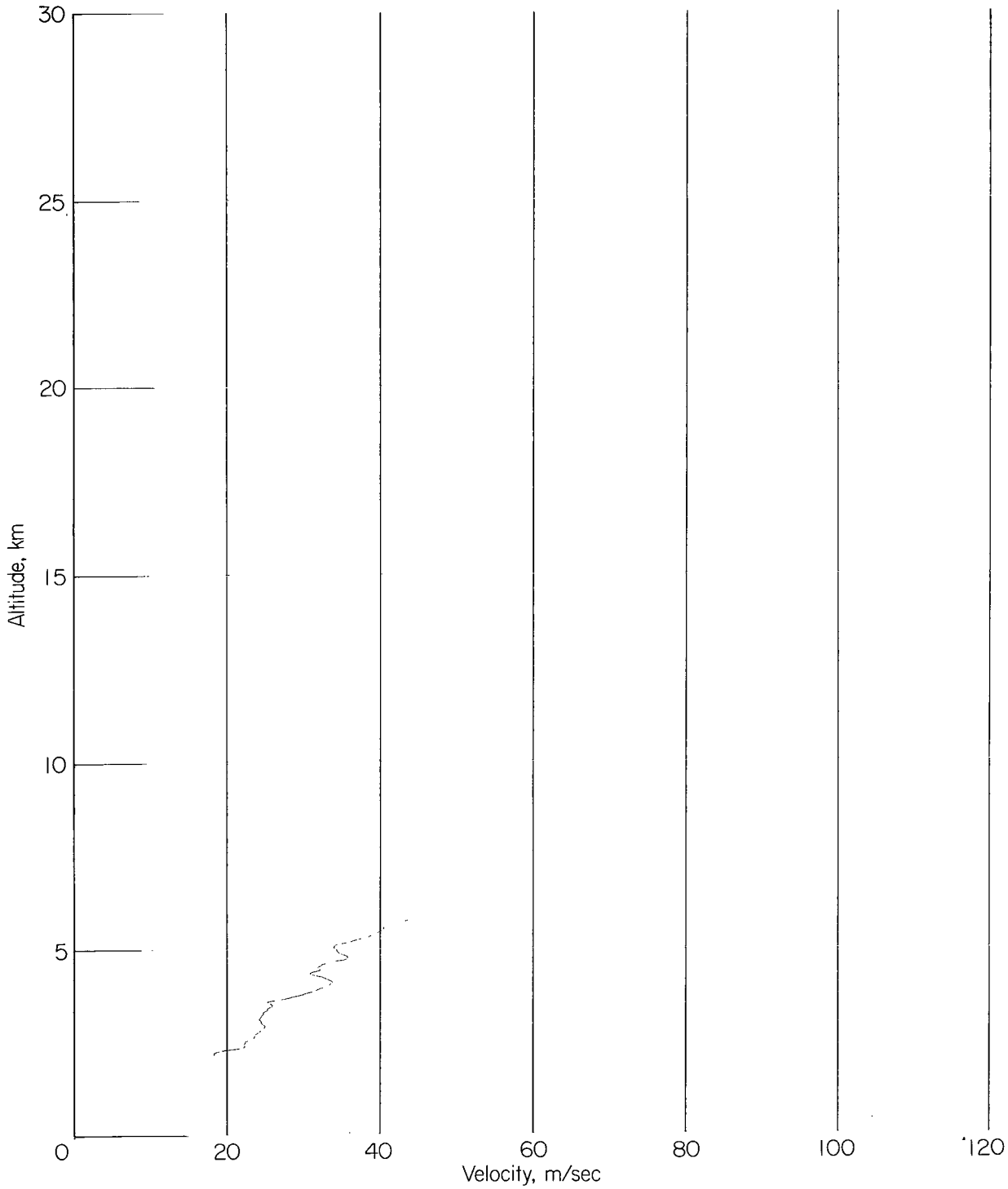
(a) West-to-east velocity component.

Figure 19.- Wind profile of smoke trail 044 obtained March 17, 1964. Time interval, 60 seconds; height interval, 25 meters.



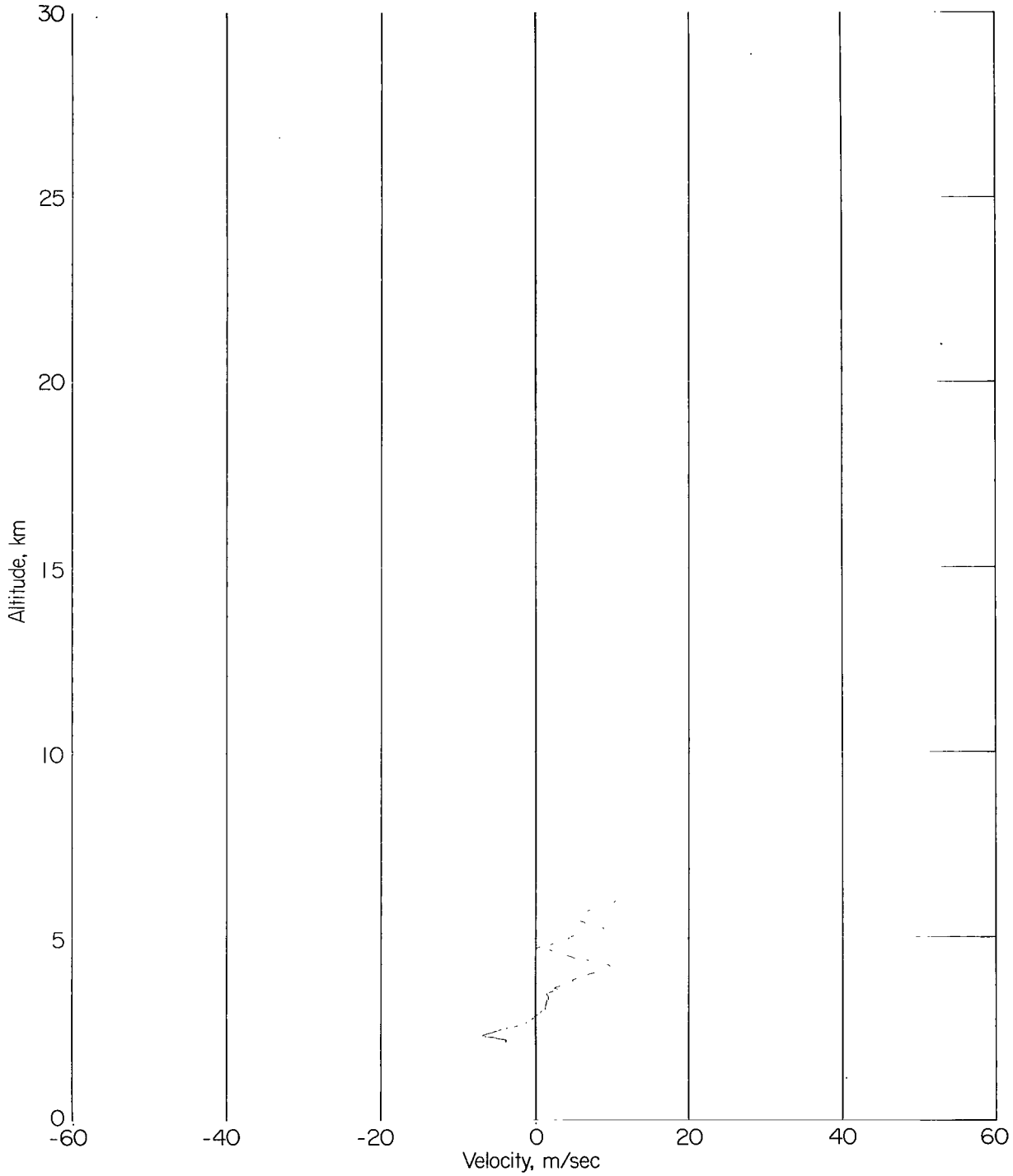
(b) South-to-north velocity component.

Figure 19.- Concluded.



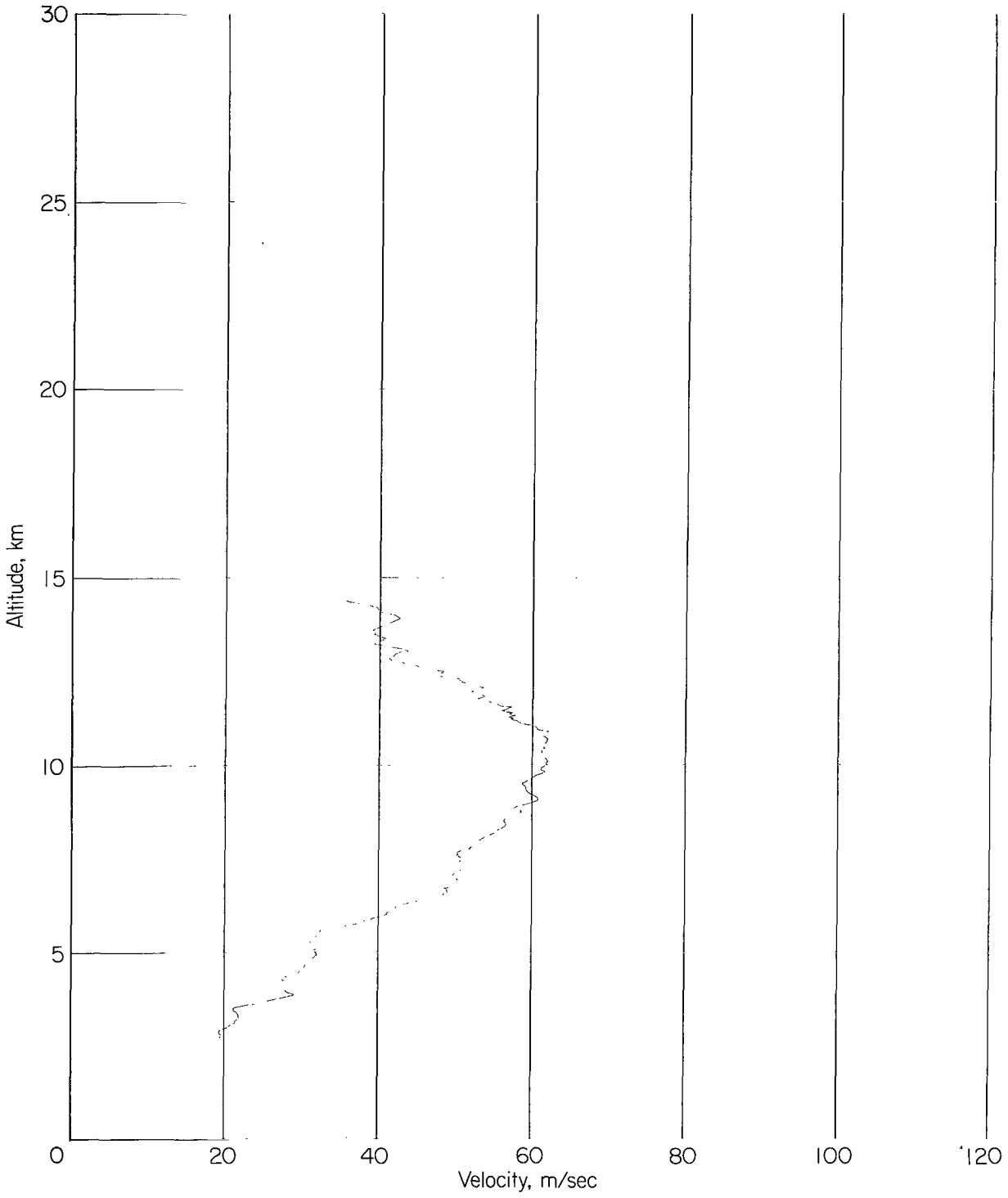
(a) West-to-east velocity component.

Figure 20.- Wind profile of smoke trail 045 obtained March 27, 1964. Time interval, 60 seconds; height interval, 25 meters.



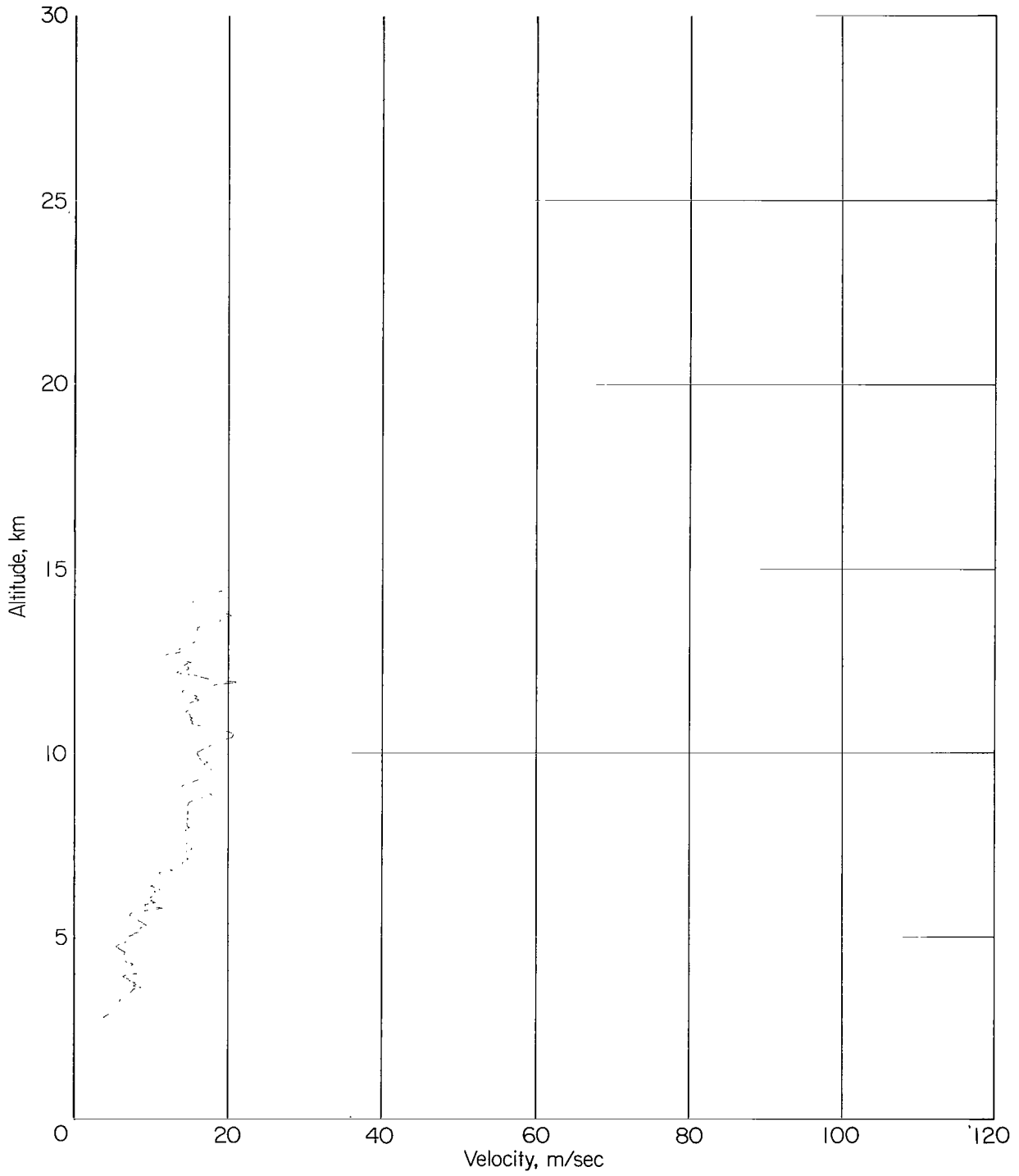
(b) South-to-north velocity component.

Figure 20.- Concluded.



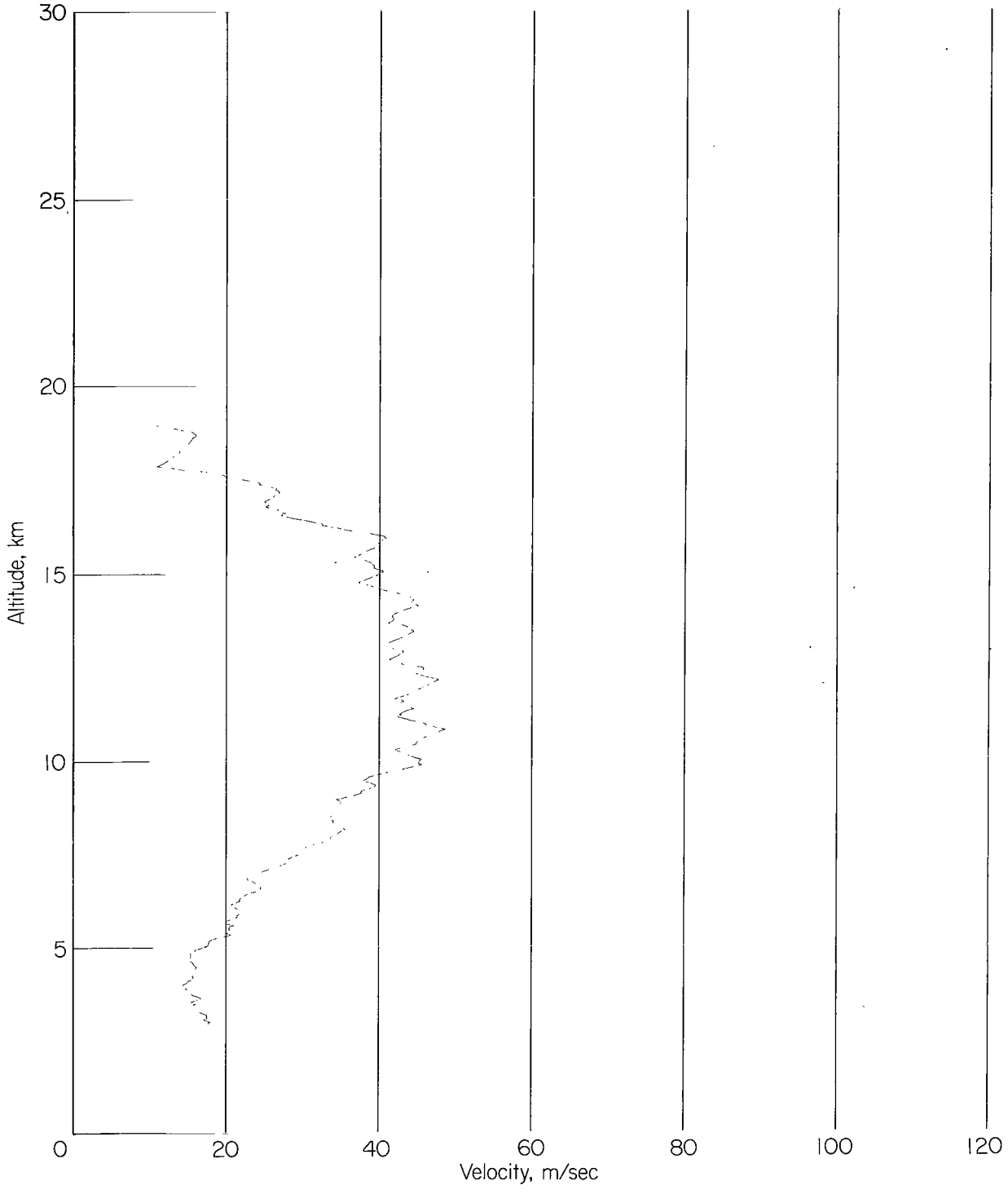
(a) West-to-east velocity component.

Figure 21.- Wind profile of smoke trail 046 obtained March 27, 1964. Time interval, 60 seconds; height interval, 25 meters.



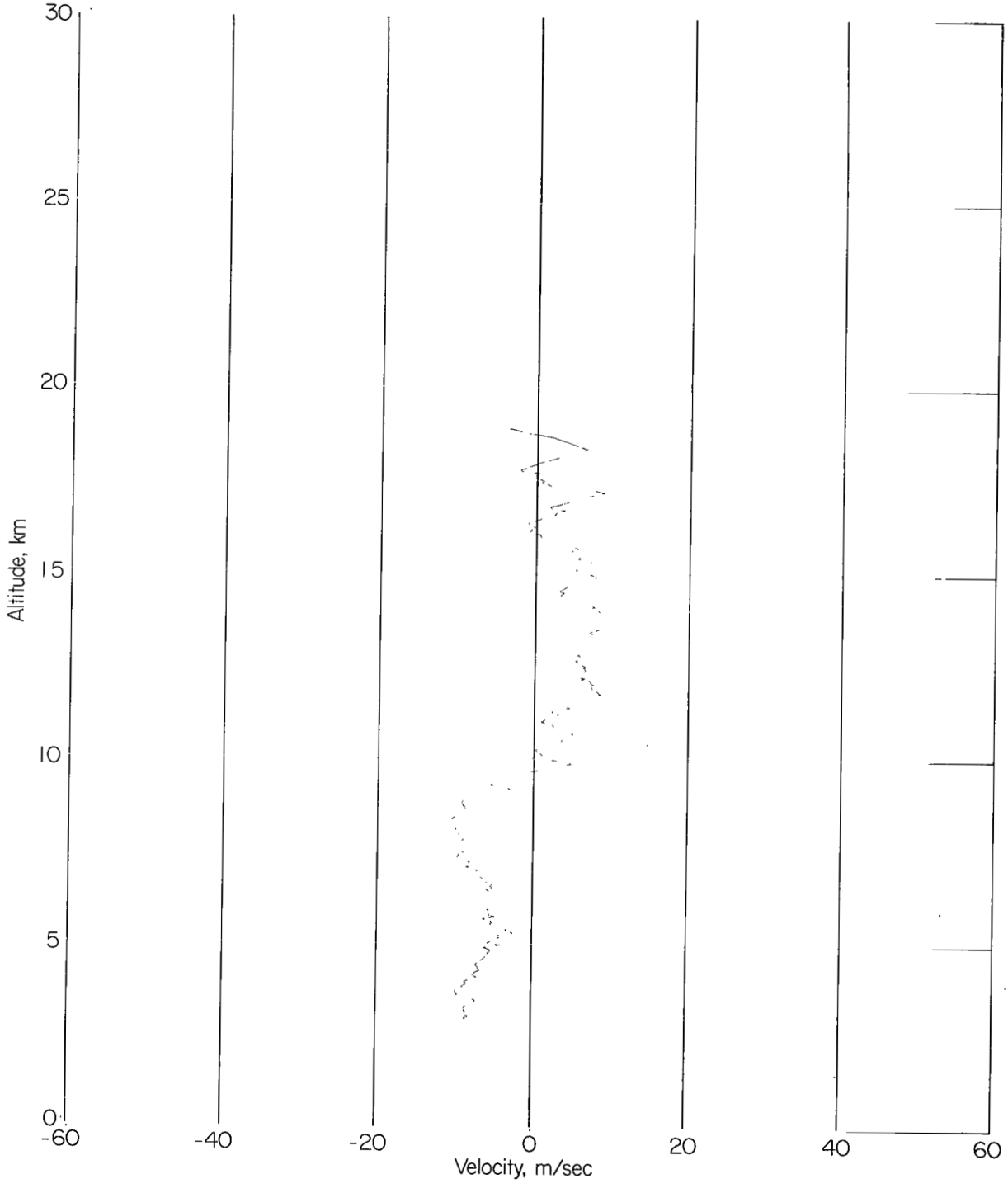
(b) South-to-north velocity component.

Figure 21.- Concluded.



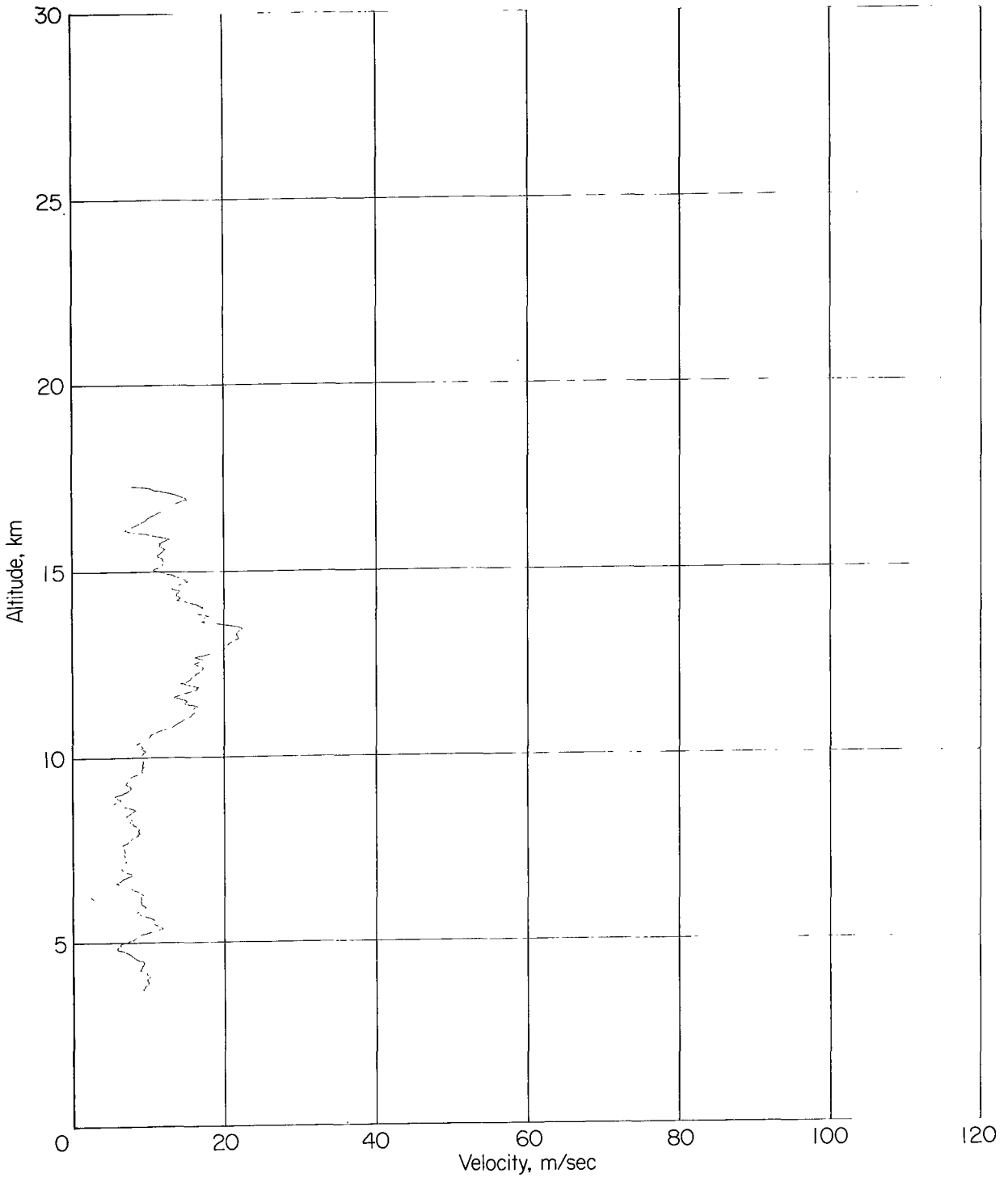
(a) West-to-east velocity component.

Figure 22.- Wind profile of smoke trail 047 obtained April 9, 1964. Time interval, 60 seconds; height interval, 25 meters.



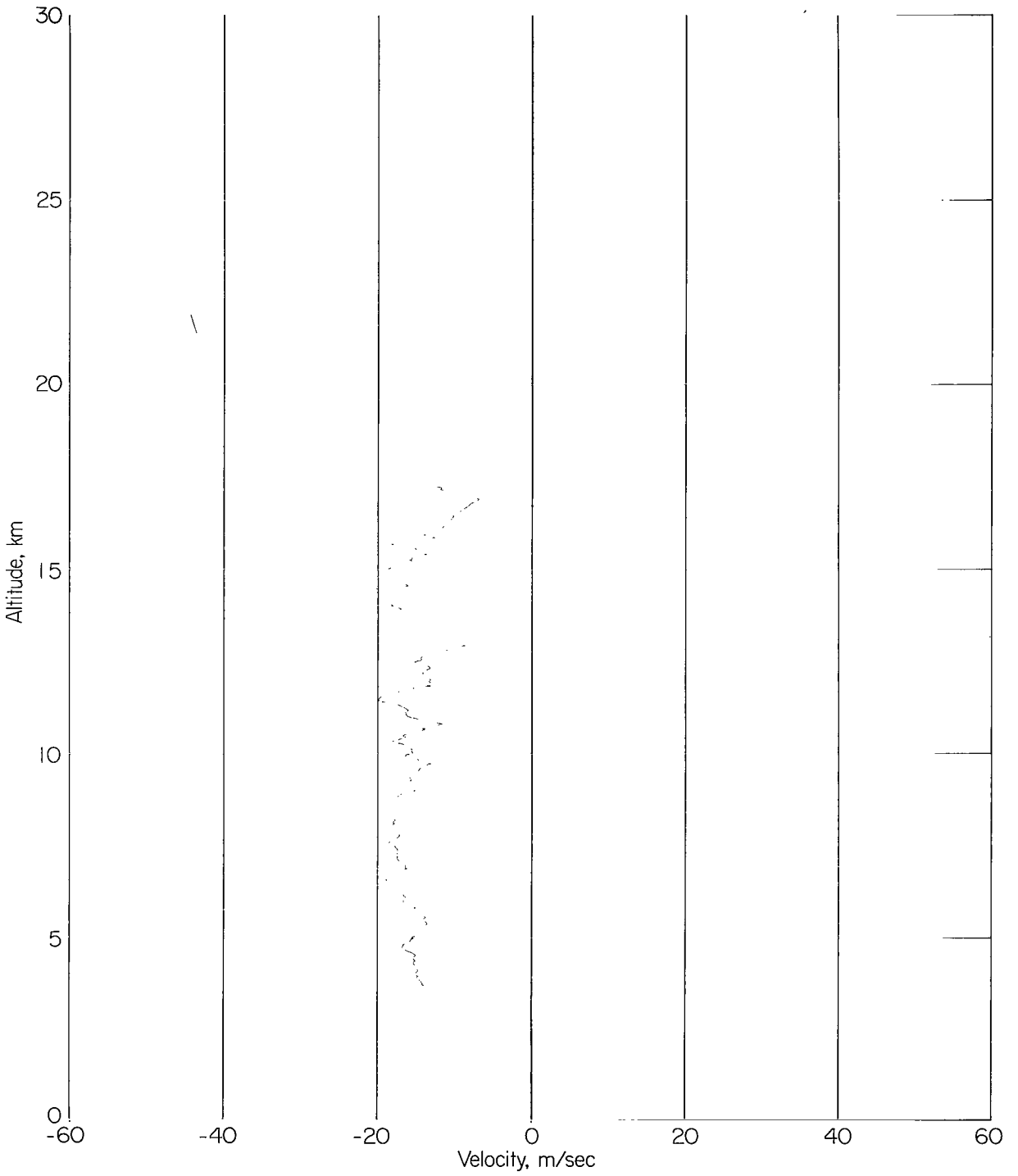
(b) South-to-north velocity component.

Figure 22.- Concluded.



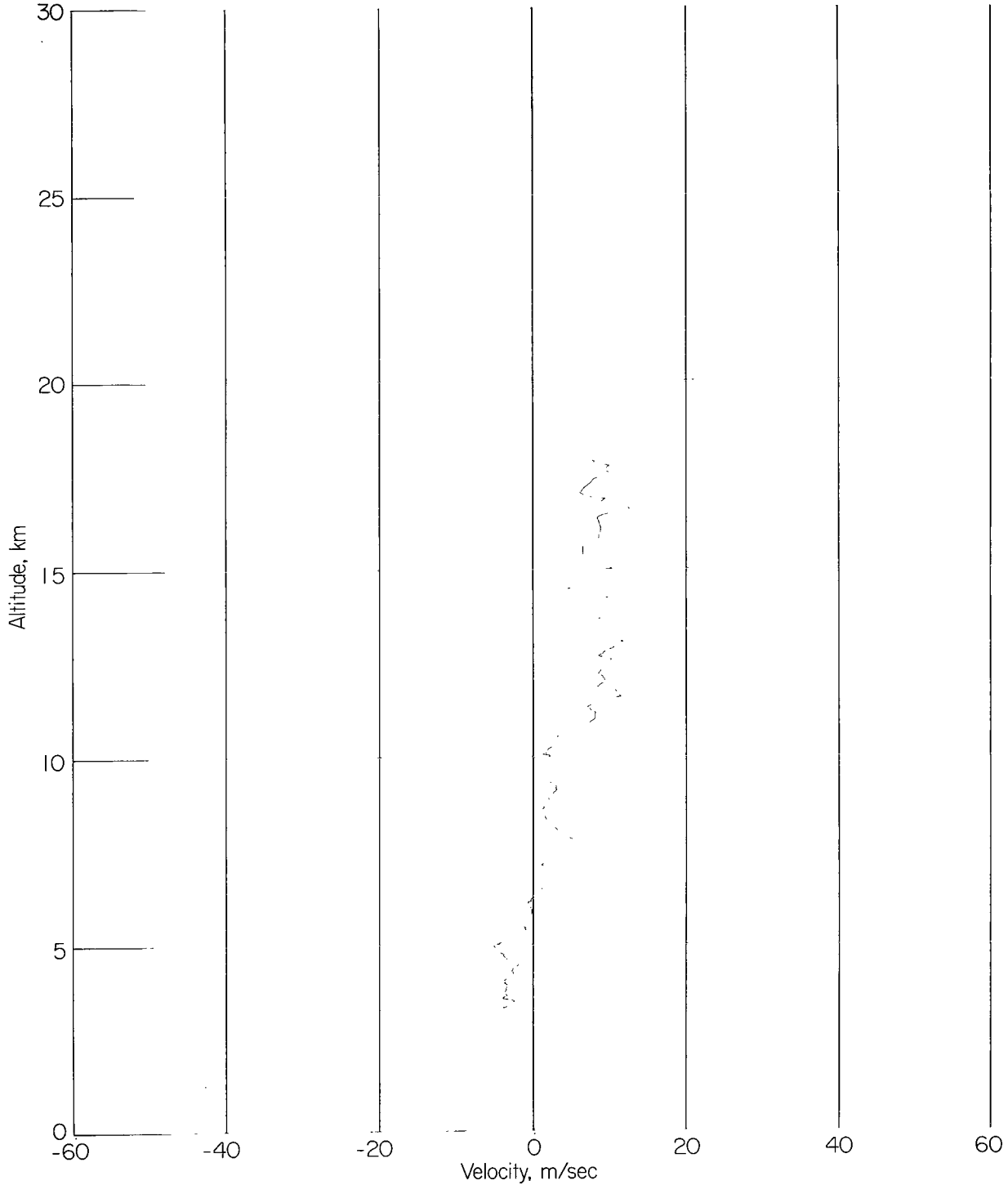
(a) West-to-east velocity component.

Figure 23.- Wind profile of smoke trail 048 obtained April 17, 1964. Time interval, 60 seconds; height interval, 25 meters.



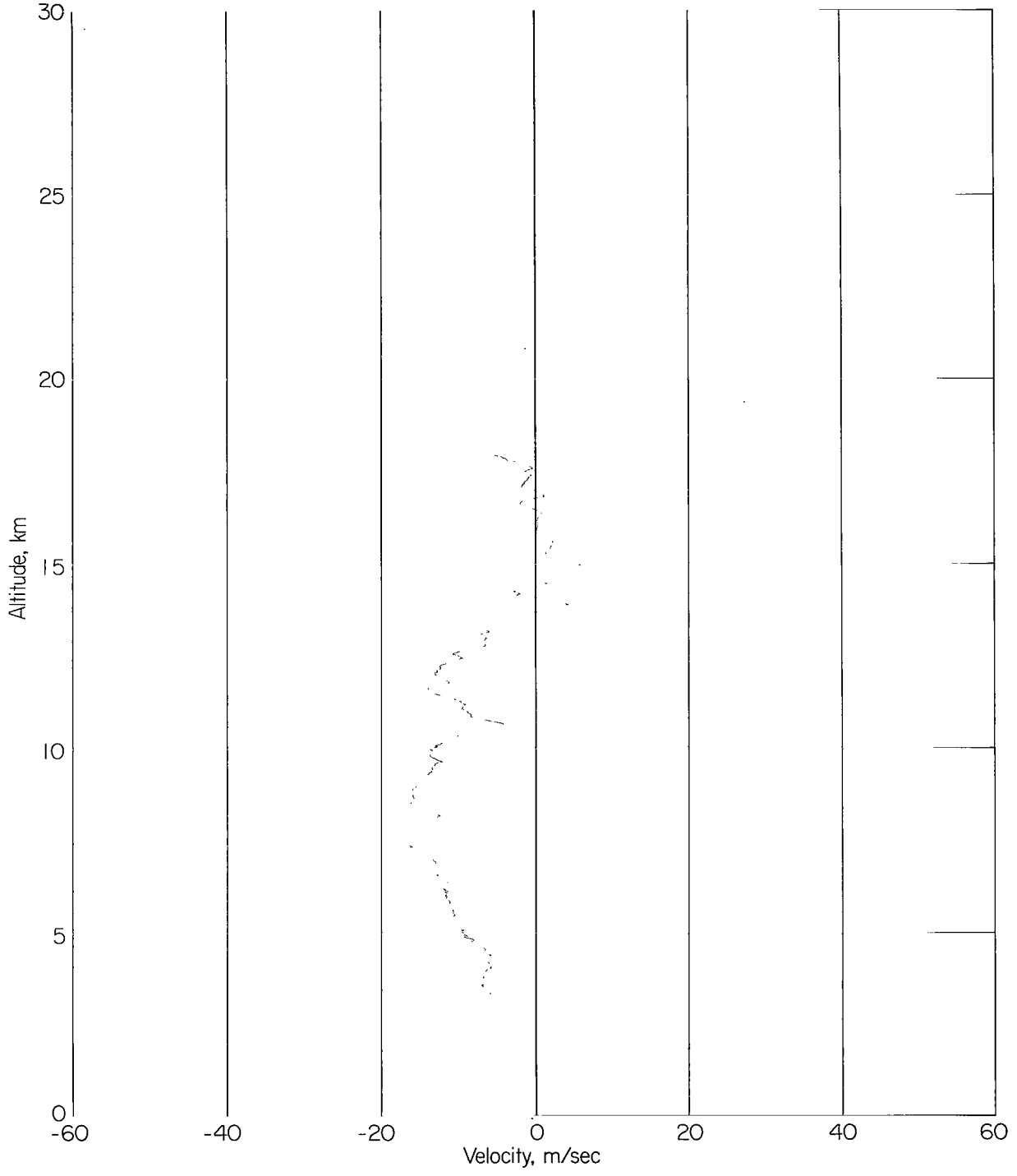
(b) South-to-north velocity component.

Figure 23.- Concluded.



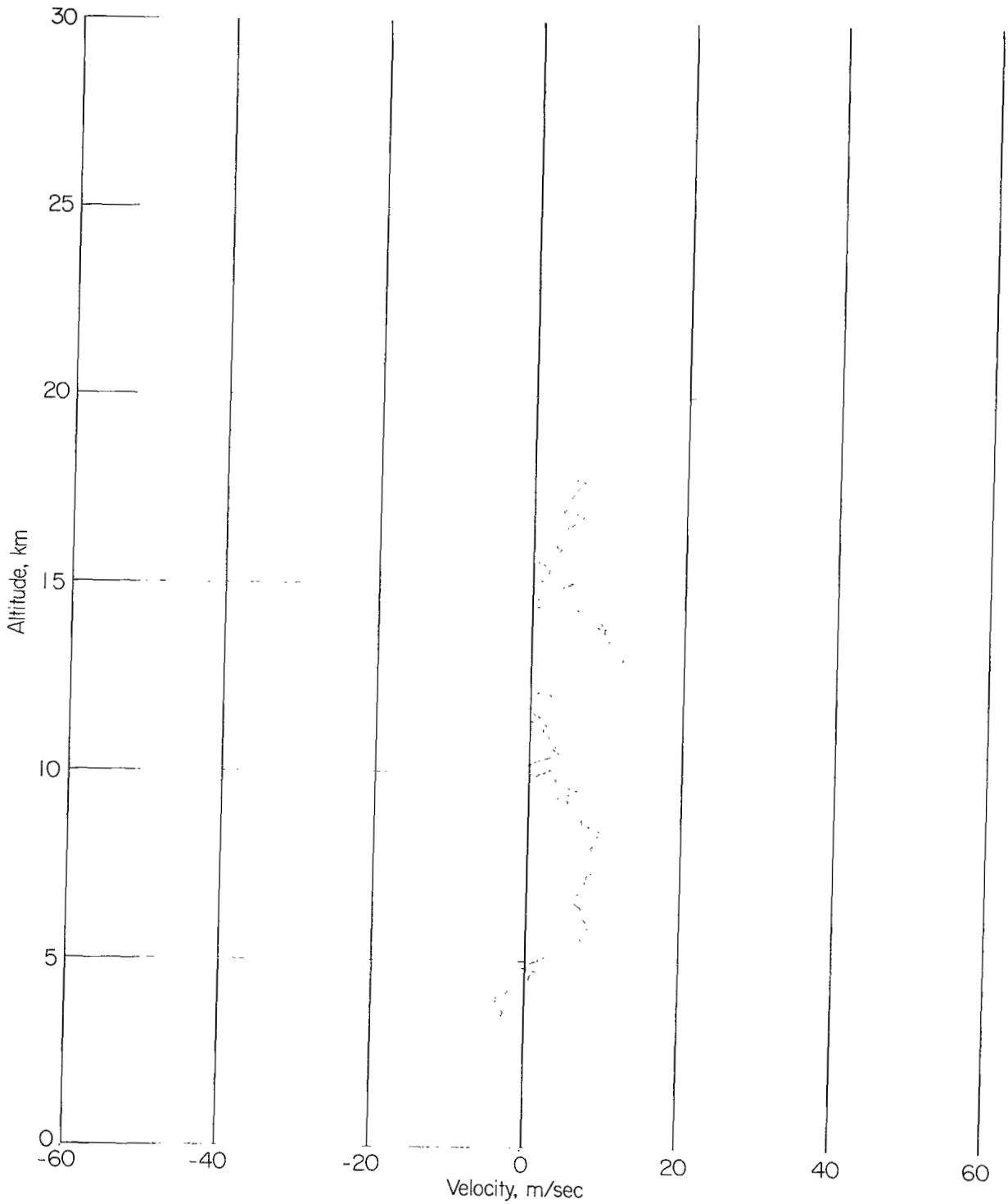
(a) West-to-east velocity component.

Figure 24.- Wind profile of smoke trail 049 obtained May 4, 1964. Time interval, 60 seconds; height interval, 25 meters.



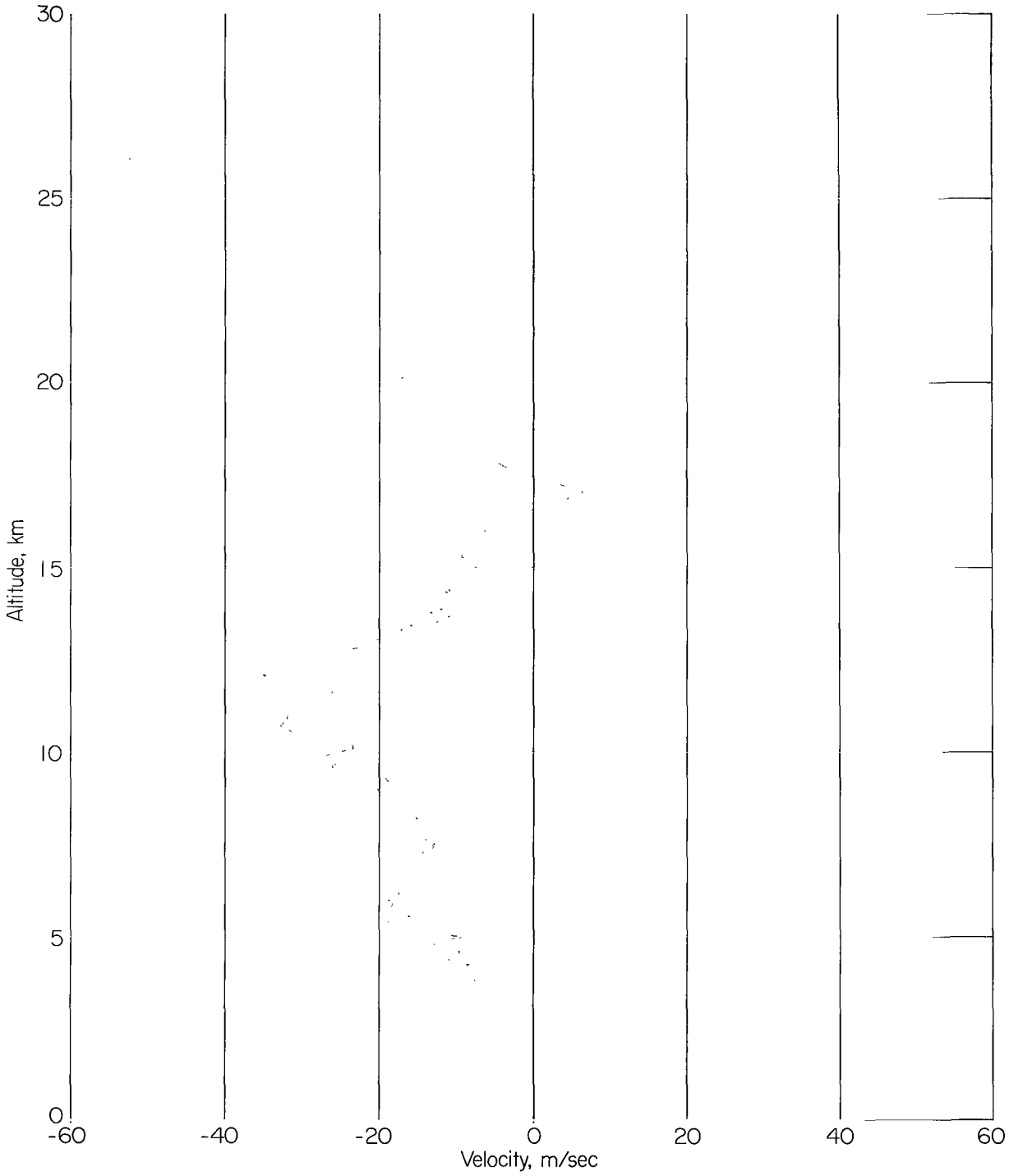
(b) South-to-north velocity component.

Figure 24.- Concluded.



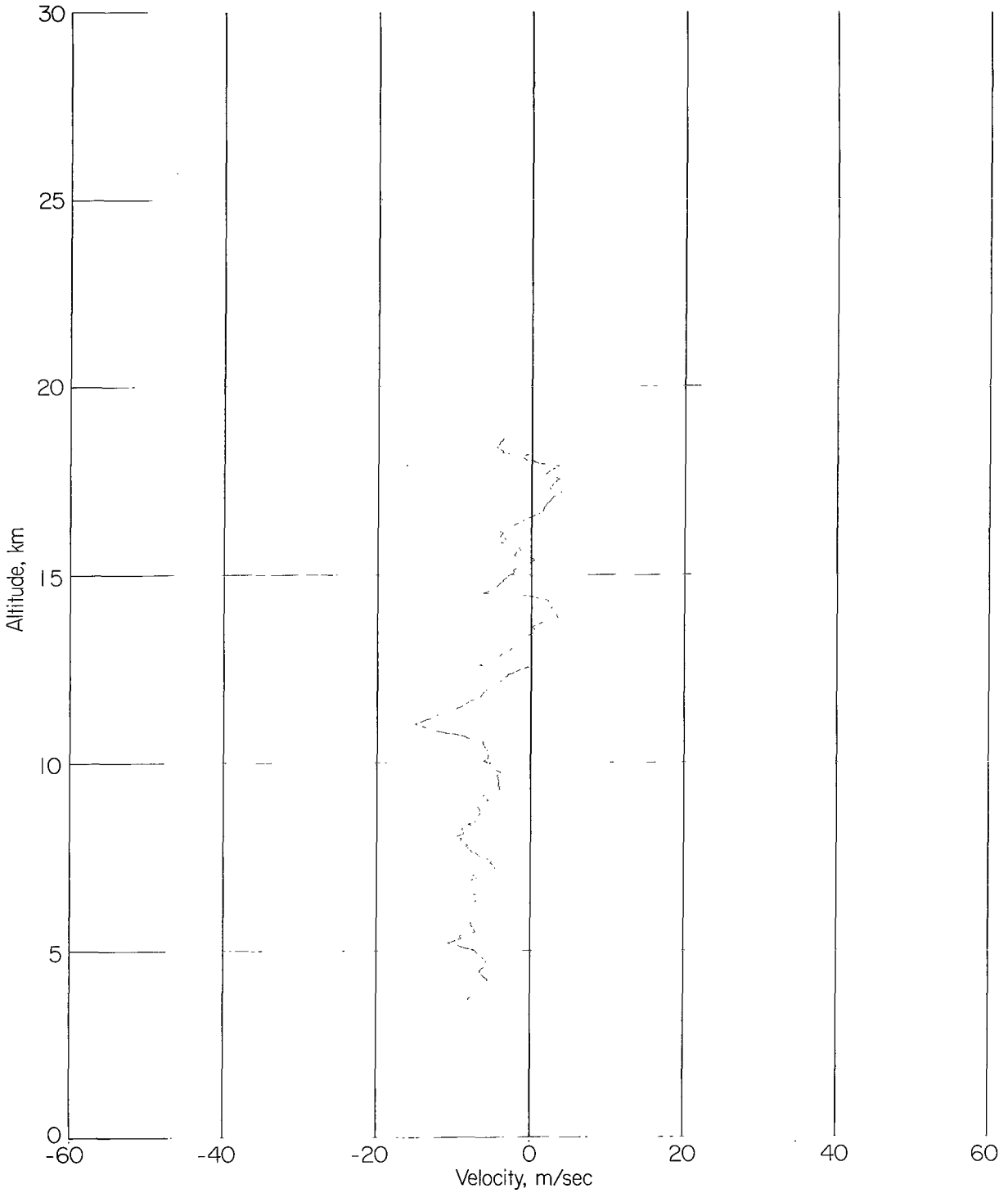
(a) West-to-east velocity component.

Figure 25.- Wind profile of smoke trail 050 obtained May 5, 1964. Time interval, 60 seconds; height interval, 25 meters.



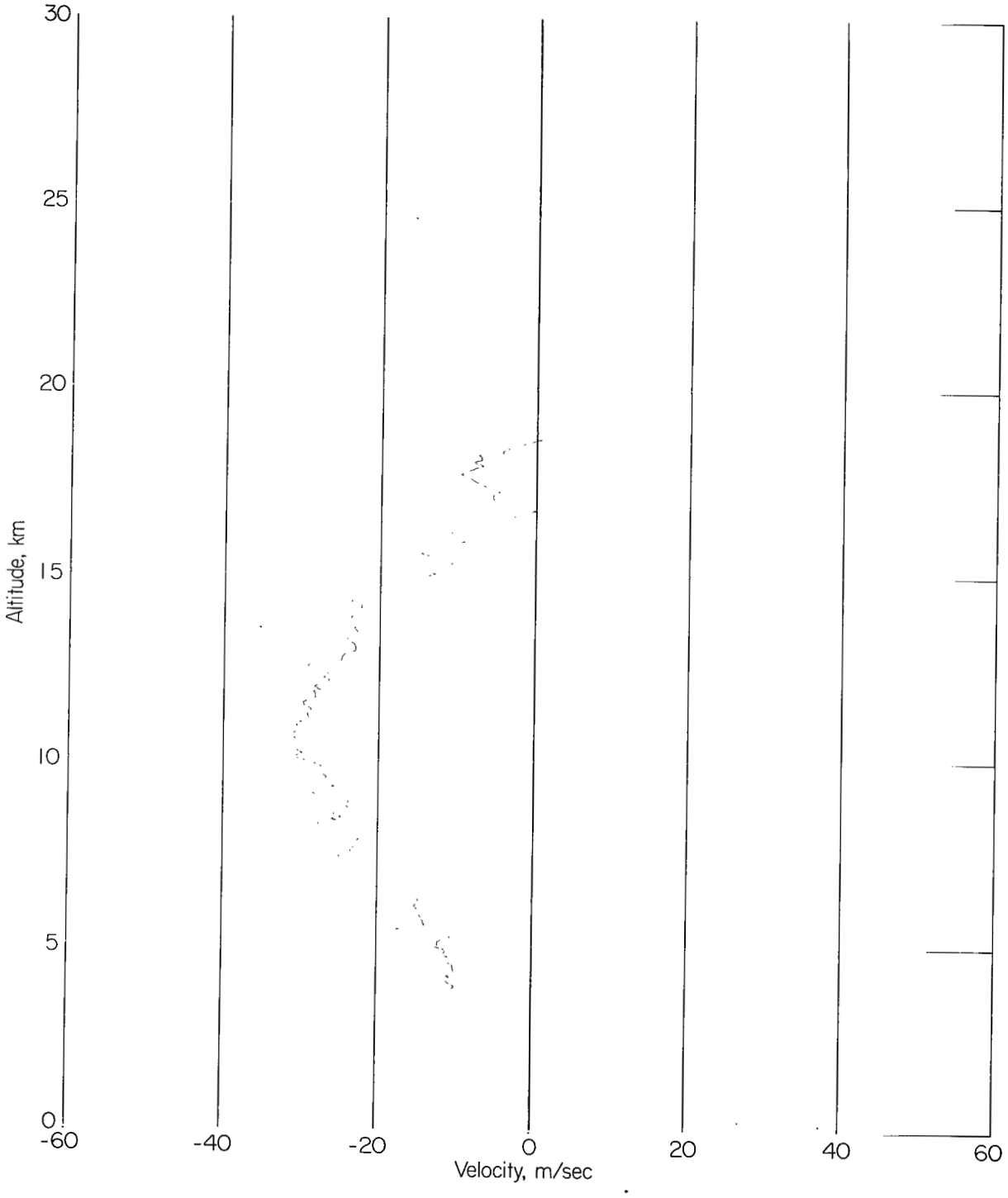
(b) South-to-north velocity component.

Figure 25.- Concluded.



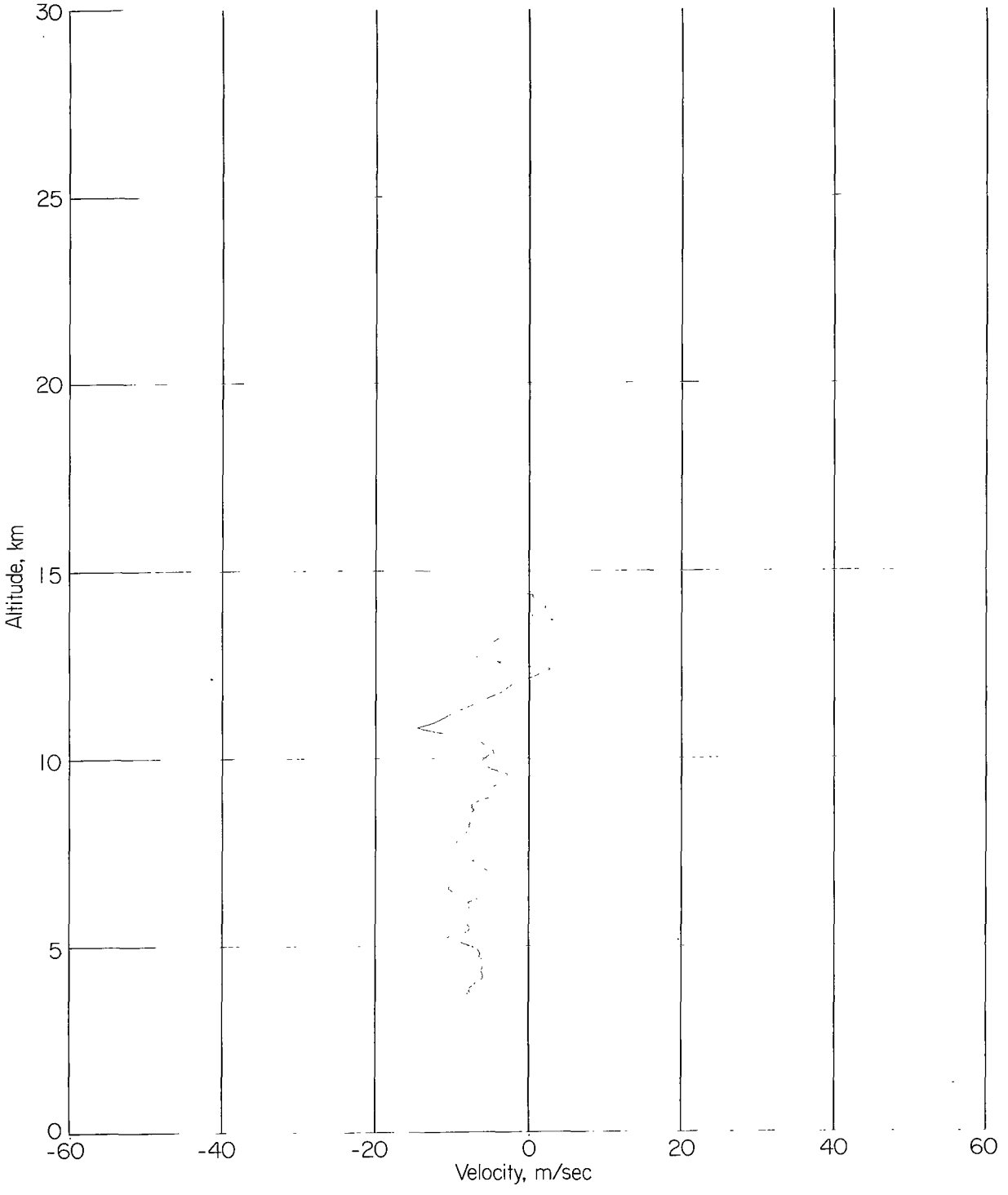
(a) West-to-east velocity component.

Figure 26.- Wind profile of smoke trail 051 obtained May 6, 1964. Time interval, 60 seconds; height interval, 25 meters.



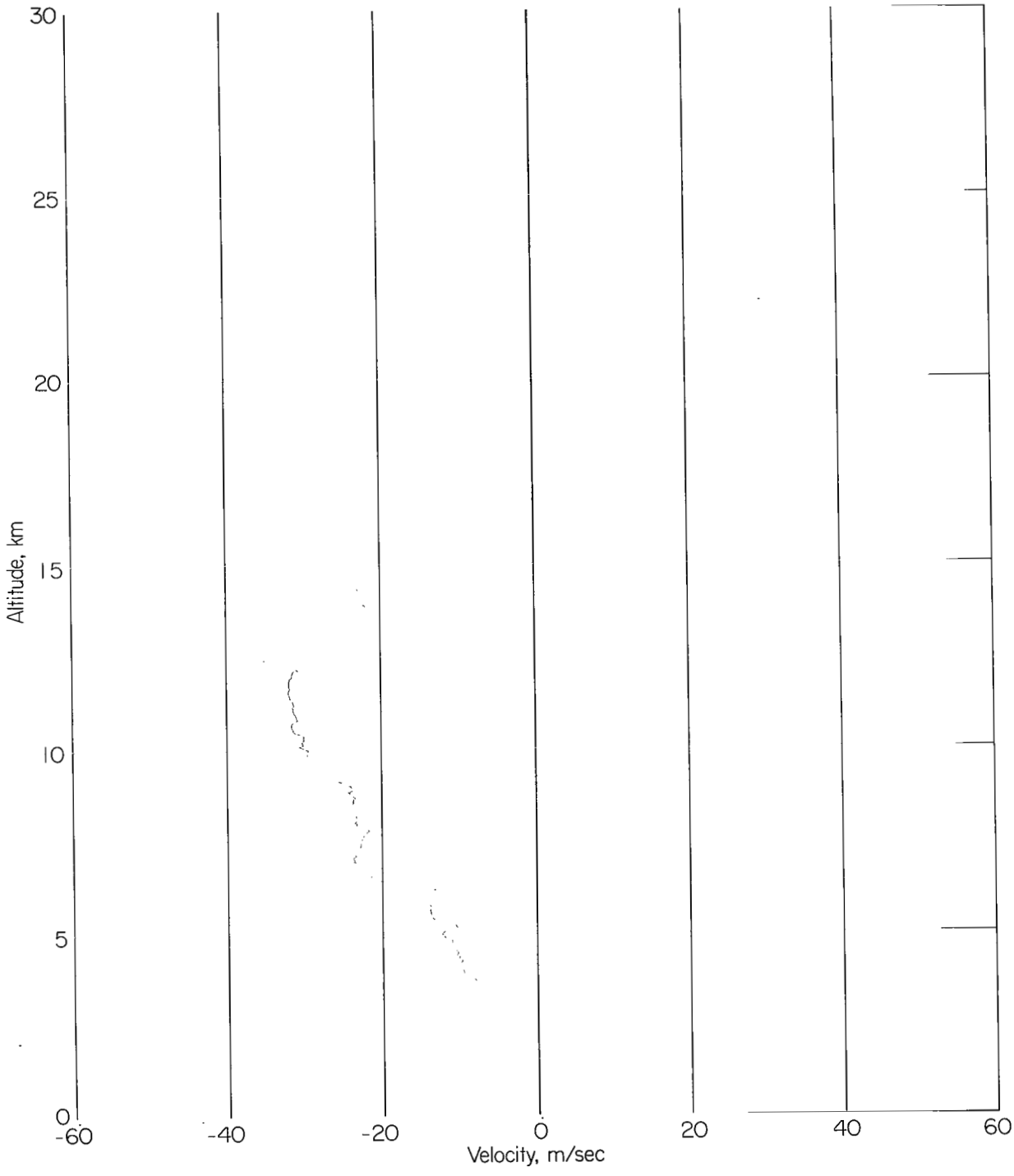
(b) South-to-north velocity component.

Figure 26.- Concluded.



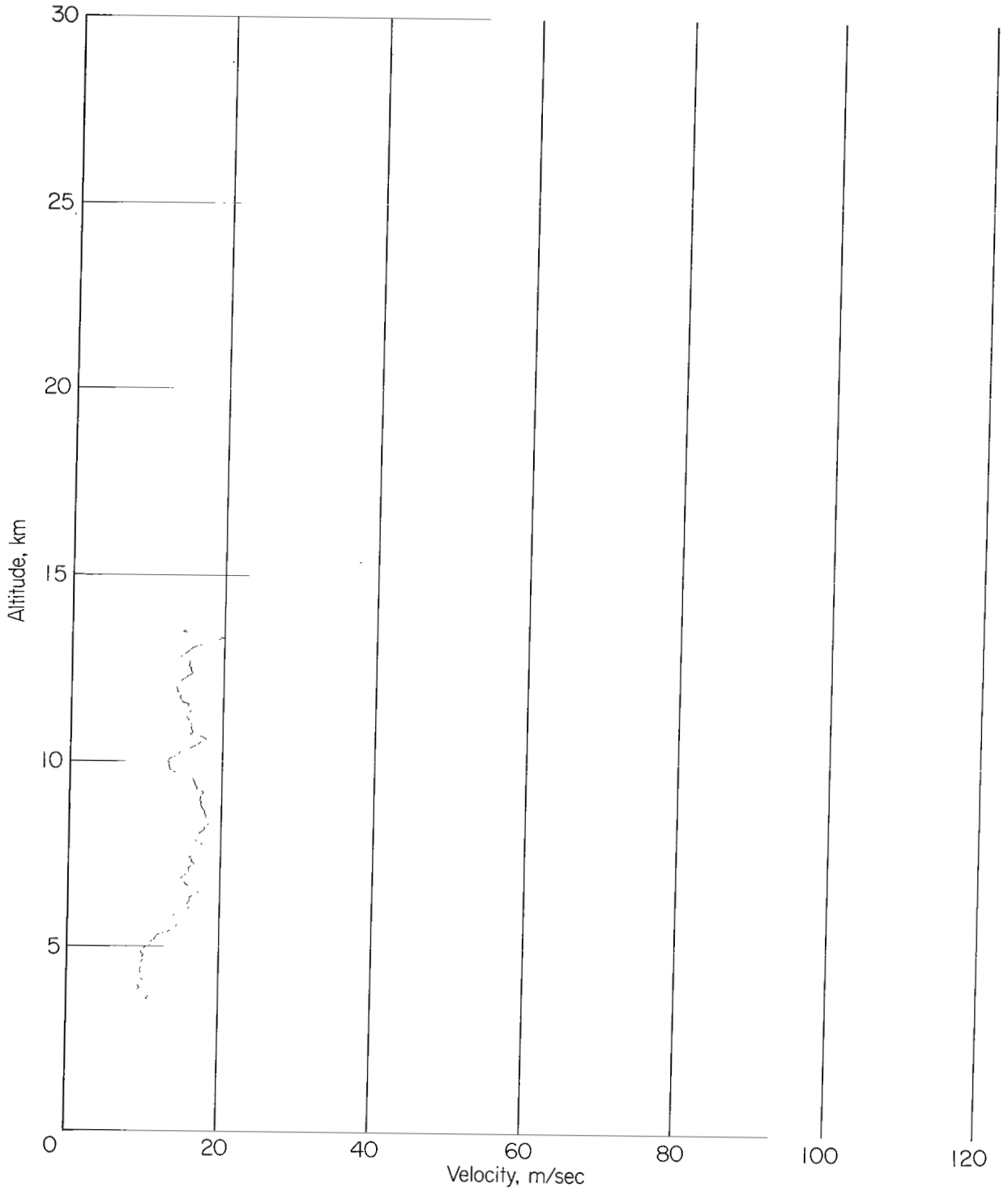
(a) West-to-east velocity component.

Figure 27.- Wind profile of smoke trail 052 obtained May 6, 1964. Time interval, 60 seconds; height interval, 25 meters.



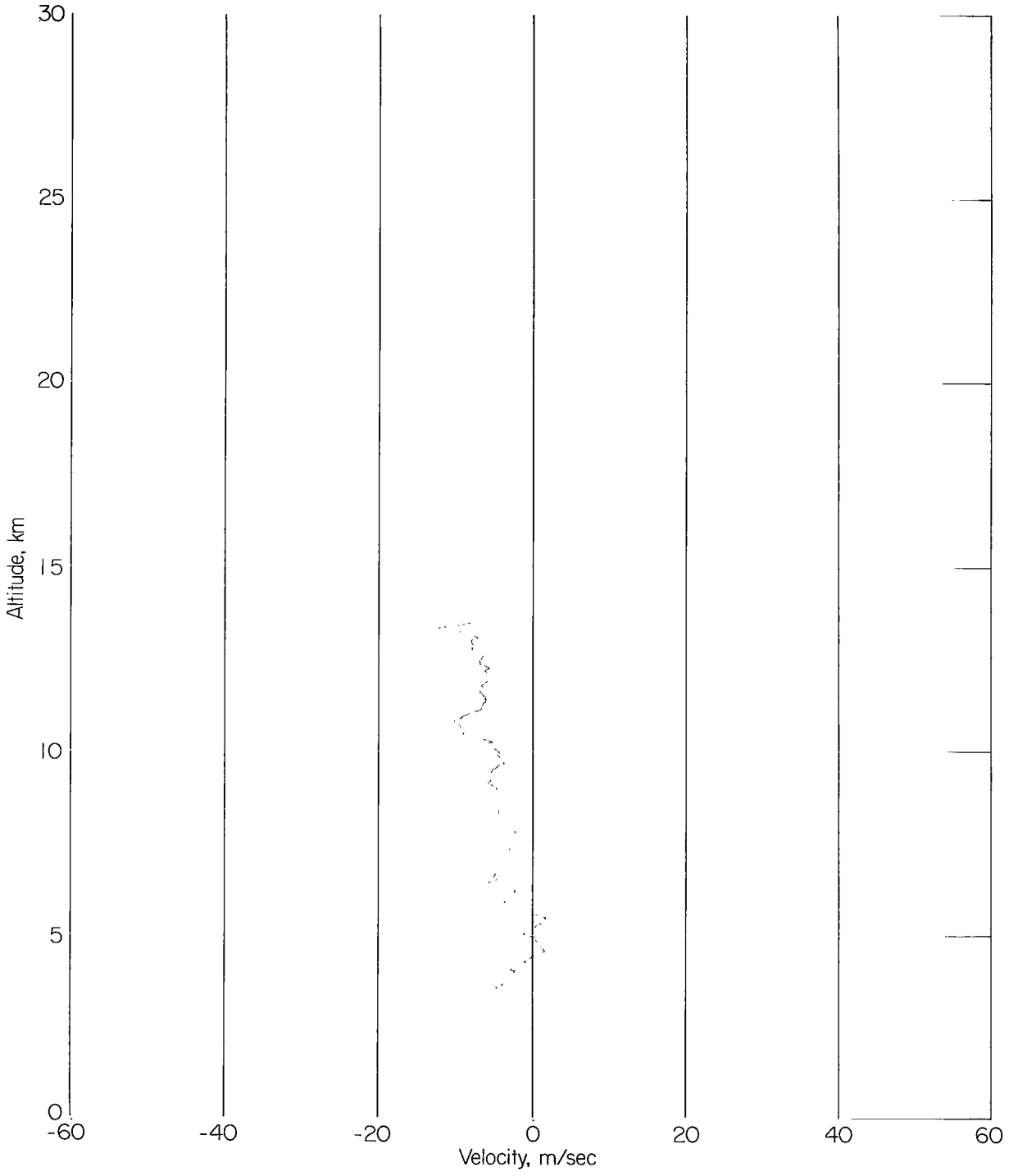
(b) South-to-north velocity component.

Figure 27.- Concluded.



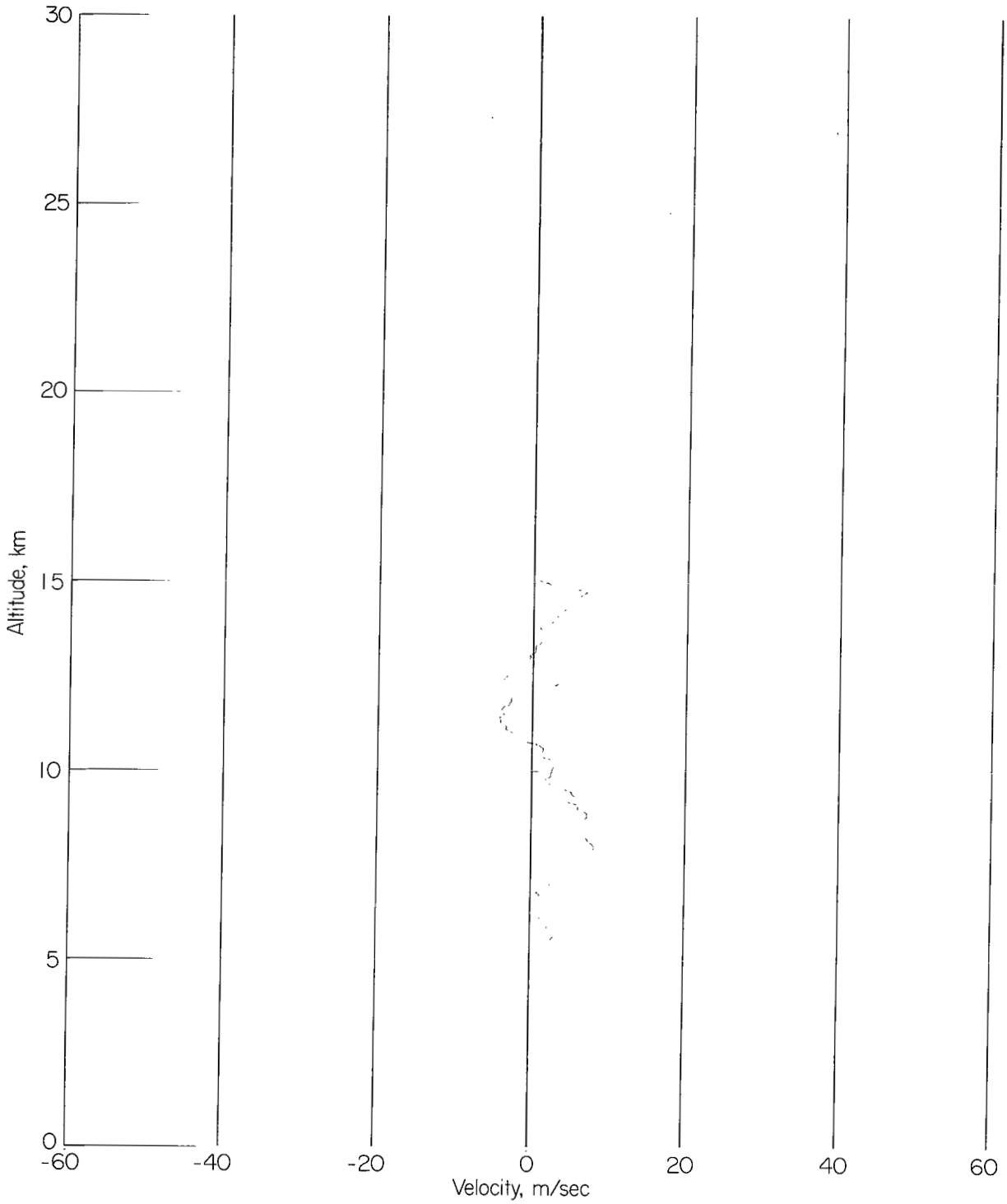
(a) West-to-east velocity component.

Figure 28.- Wind profile of smoke trail 053 obtained May 19, 1964. Time interval, 60 seconds; height interval, 25 meters.



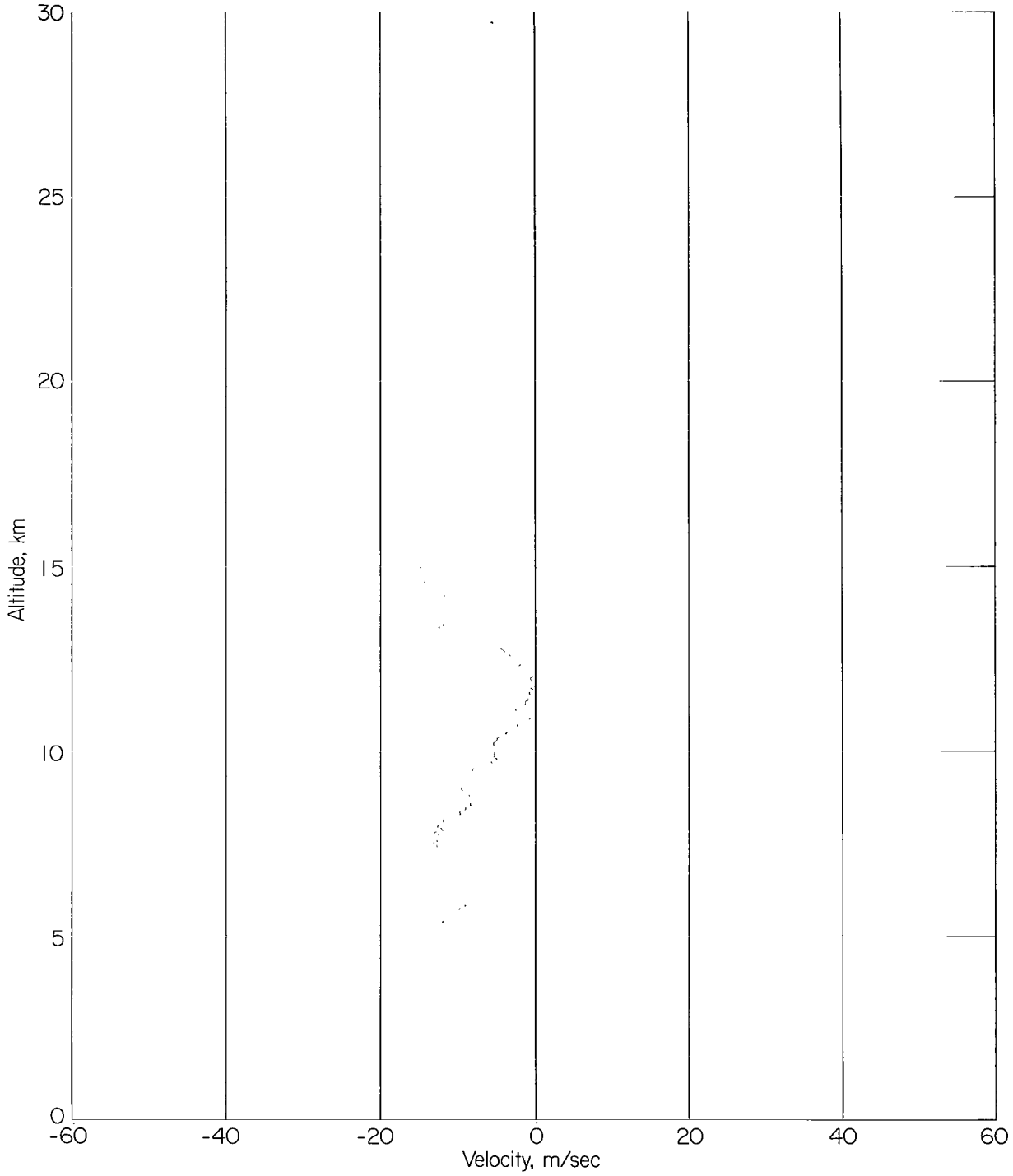
(b) South-to-north velocity component.

Figure 28.- Concluded.



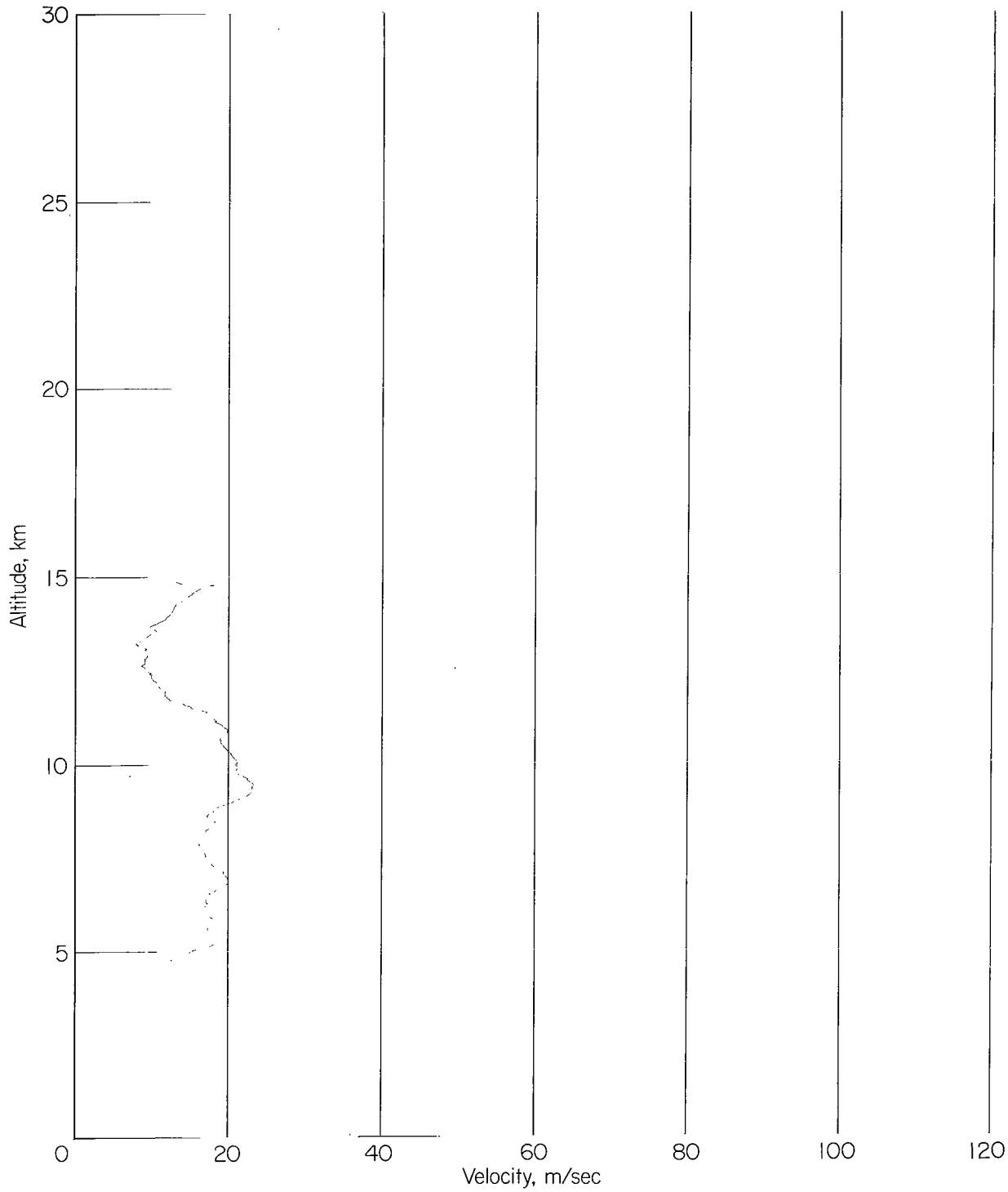
(a) West-to-east velocity component.

Figure 29.- Wind profile of smoke trail 054 obtained May 22, 1964. Time interval, 60 seconds; height interval, 25 meters.



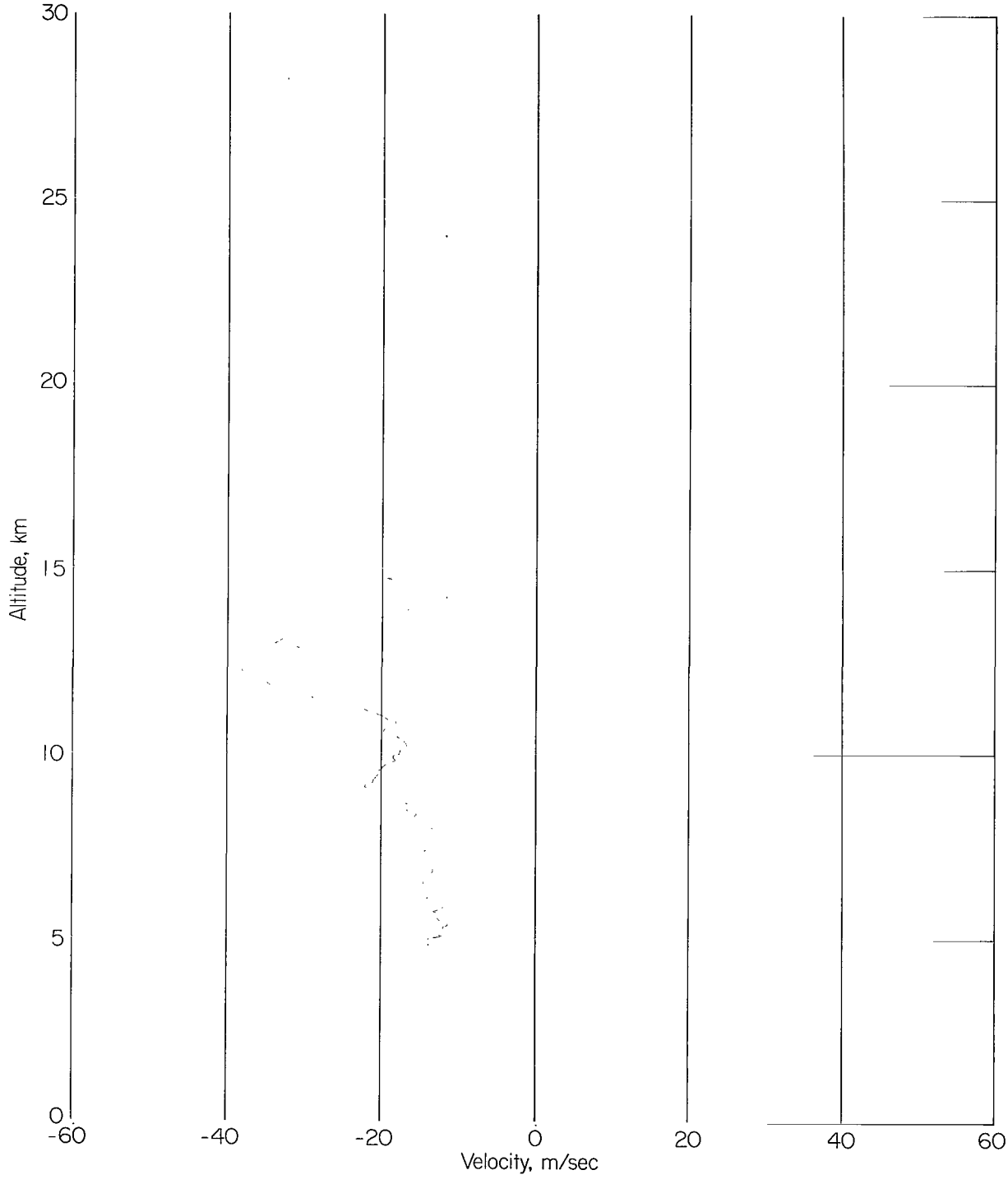
(b) South-to-north velocity component.

Figure 29.- Concluded.



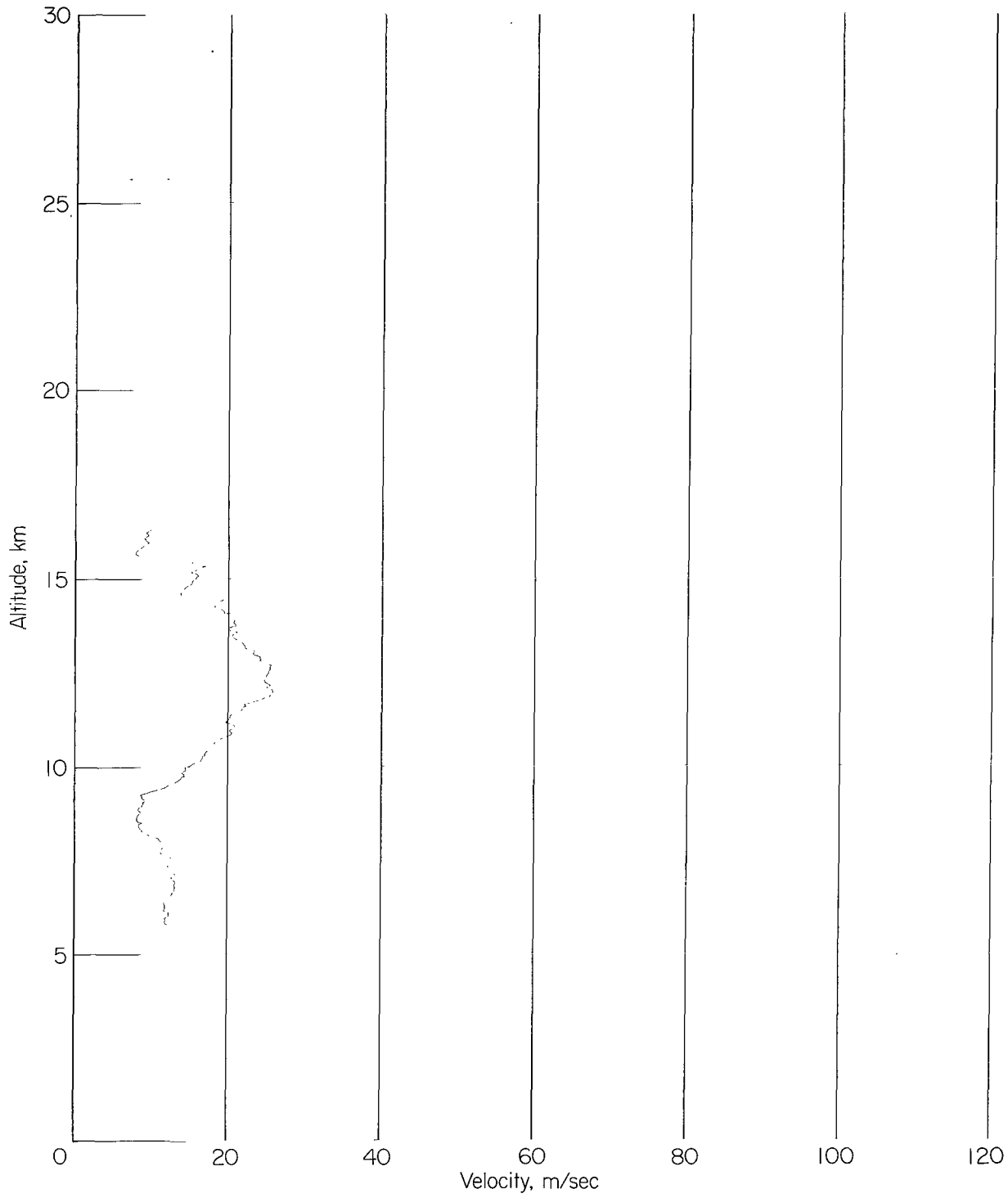
(a) West-to-east velocity component.

Figure 30.- Wind profile of smoke trail 055 obtained June 11, 1964. Time interval, 60 seconds; height interval, 25 meters.



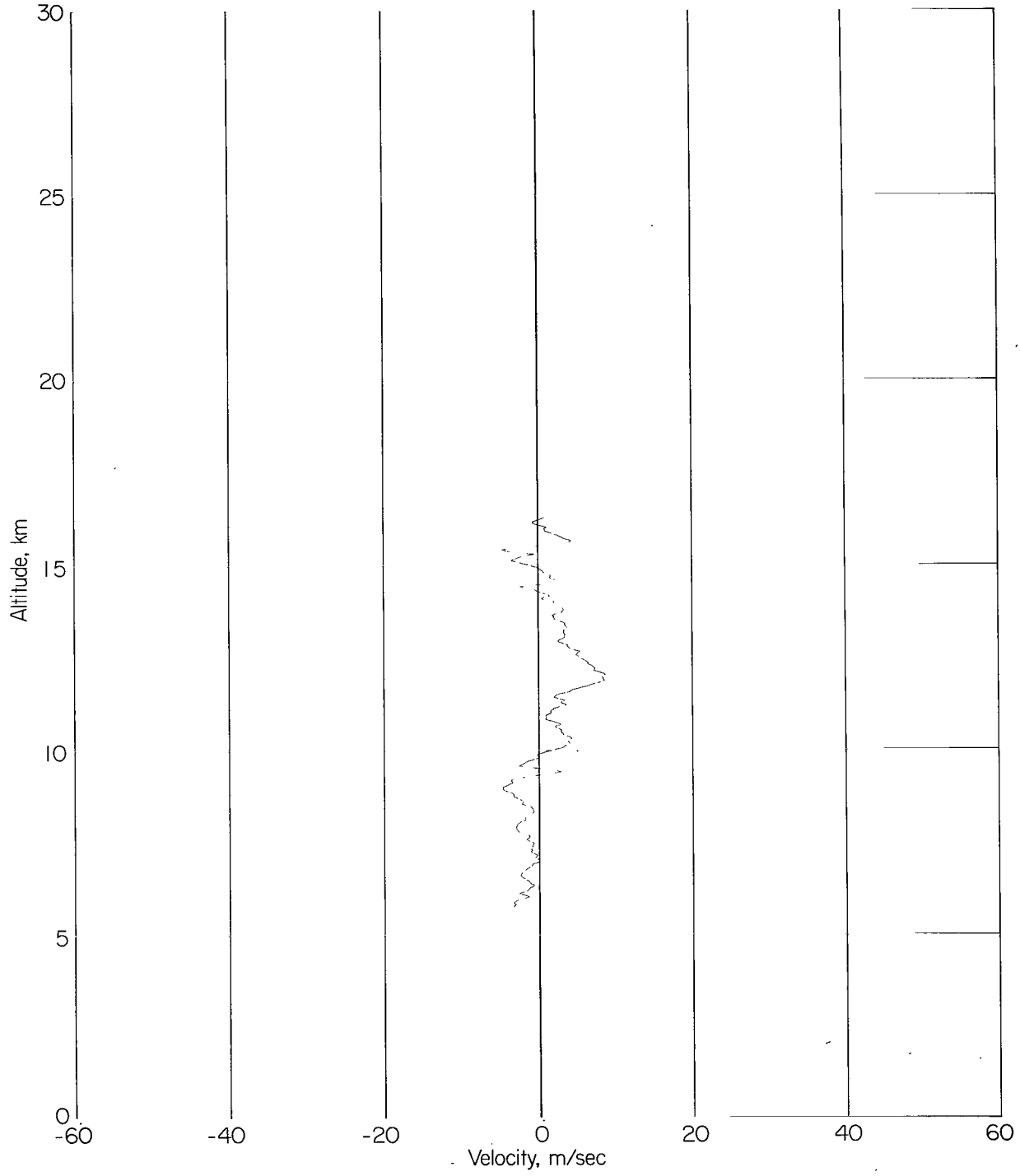
(b) South-to-north velocity component.

Figure 30.- Concluded.



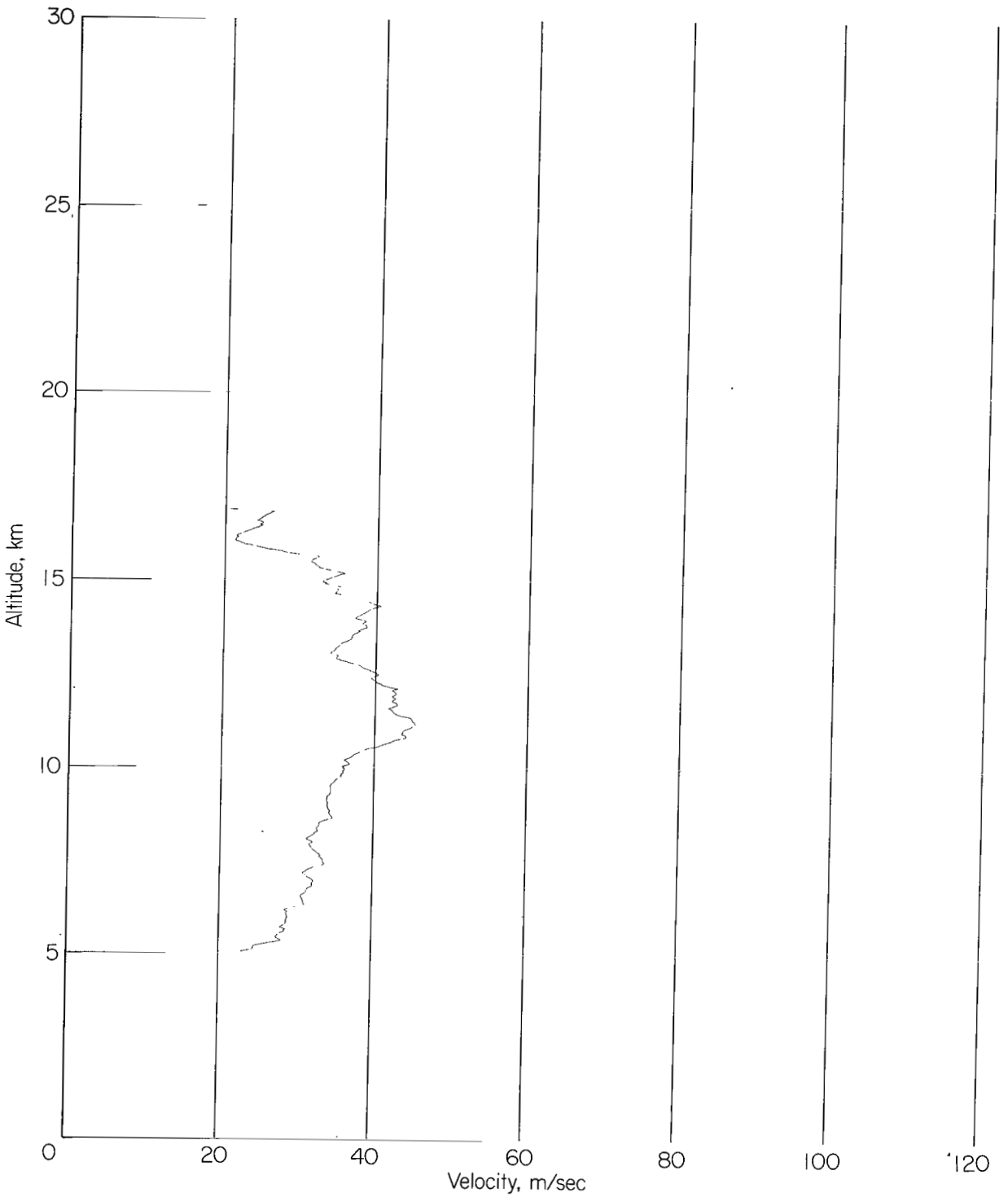
(a) West-to-east velocity component.

Figure 31.- Wind profile of smoke trail 056 obtained July 30, 1964. Time interval, 60 seconds; height interval, 25 meters.



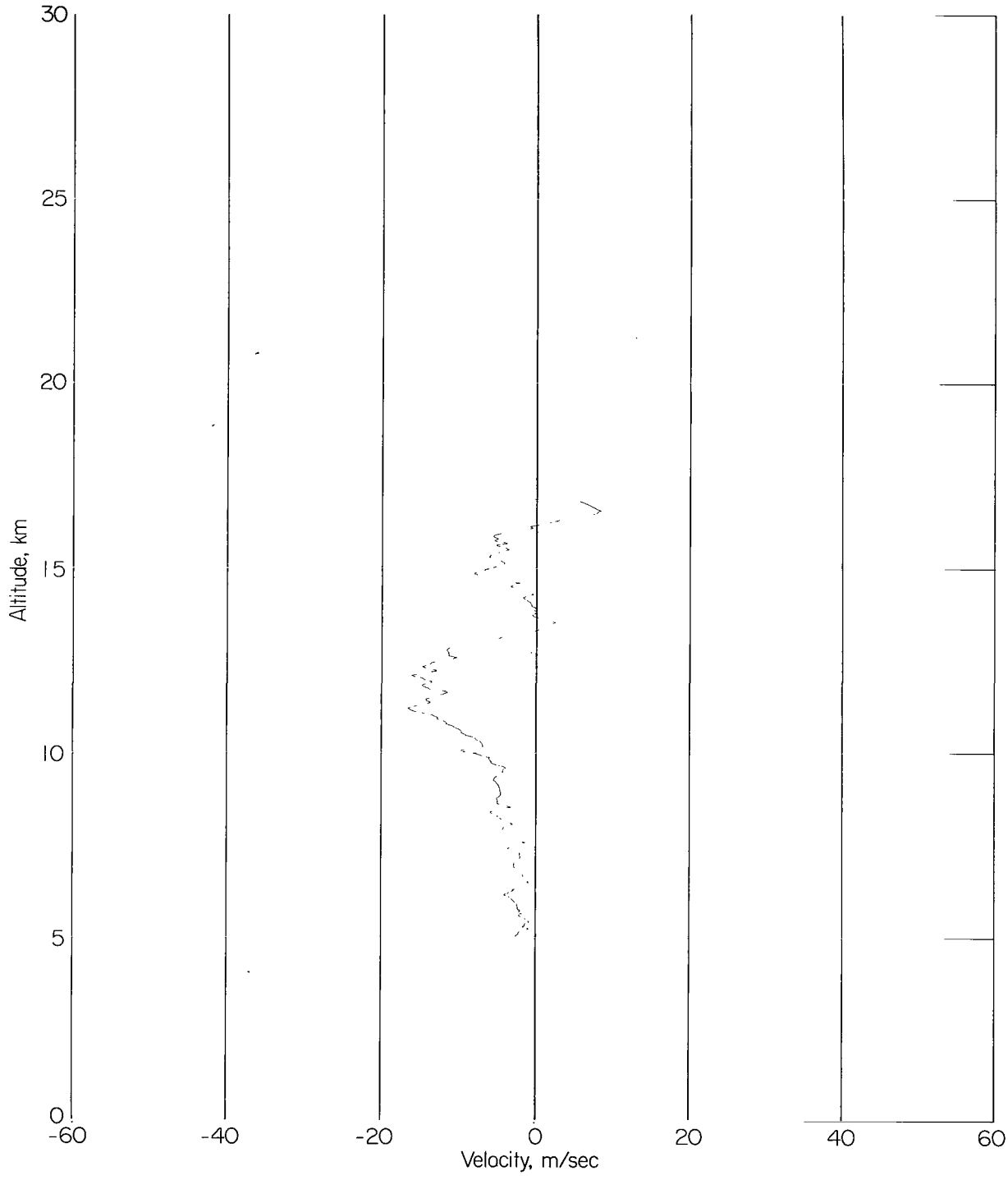
(b) South-to-north velocity component.

Figure 31.- Concluded.



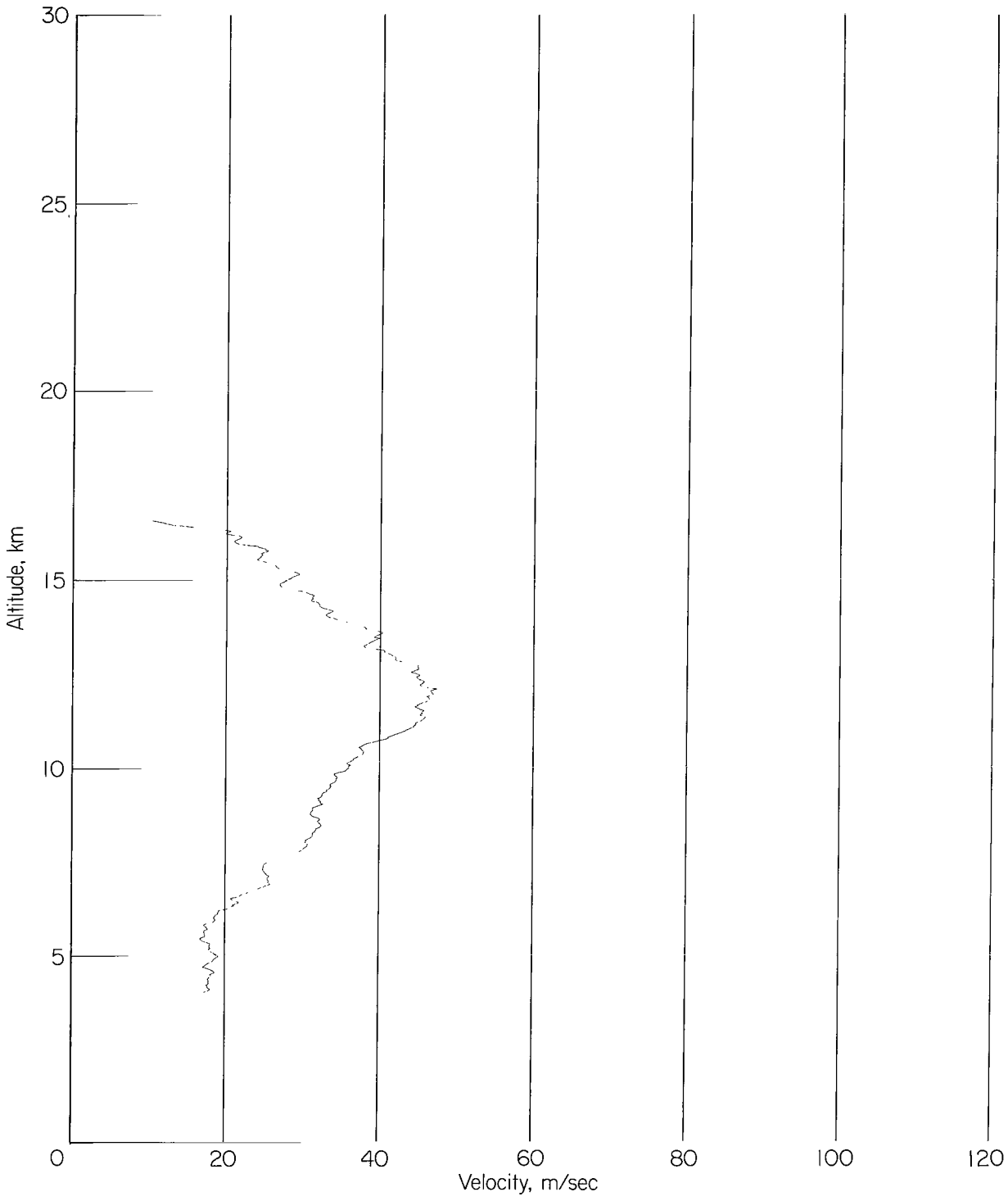
(a) West-to-east velocity component.

Figure 32.- Wind profile of smoke trail 057 obtained August 14, 1964. Time interval, 60 seconds; height interval, 25 meters.



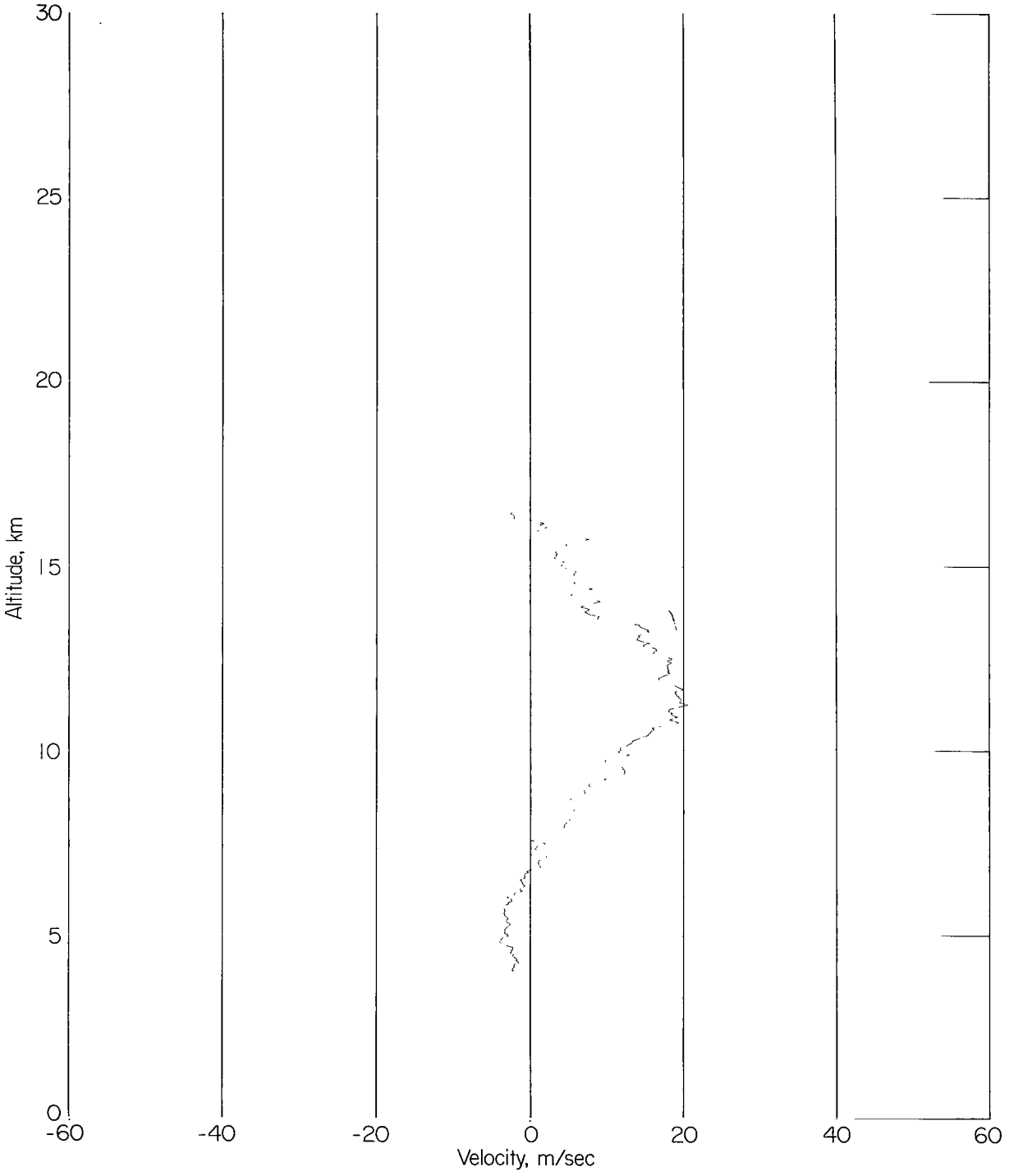
(b) South-to-north velocity component.

Figure 32.- Concluded.



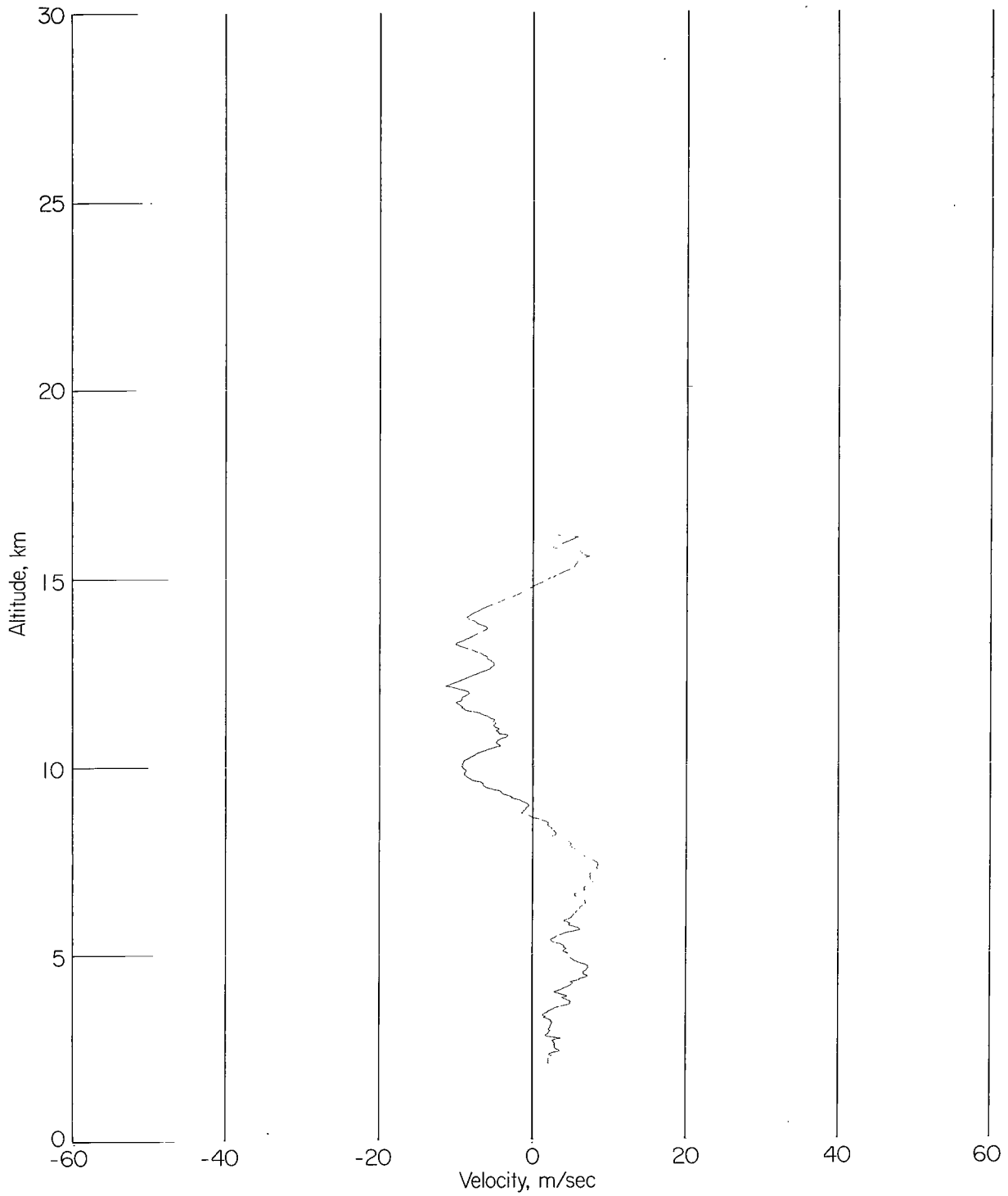
(a) West-to-east velocity component.

Figure 33.- Wind profile of smoke trail 058 obtained August 19, 1964. Time interval, 60 seconds; height interval, 25 meters.



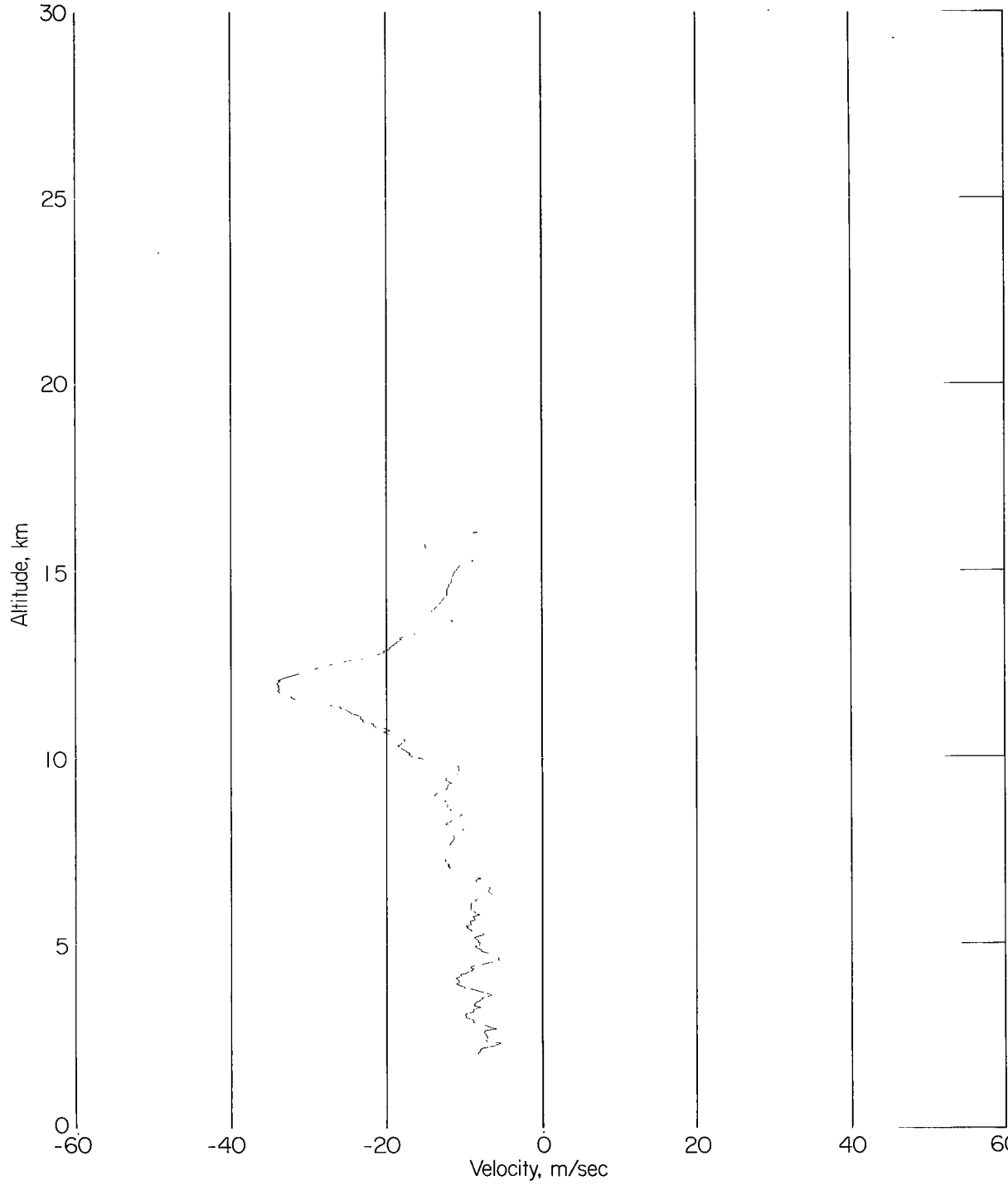
(b) South-to-north velocity component.

Figure 33.- Concluded.



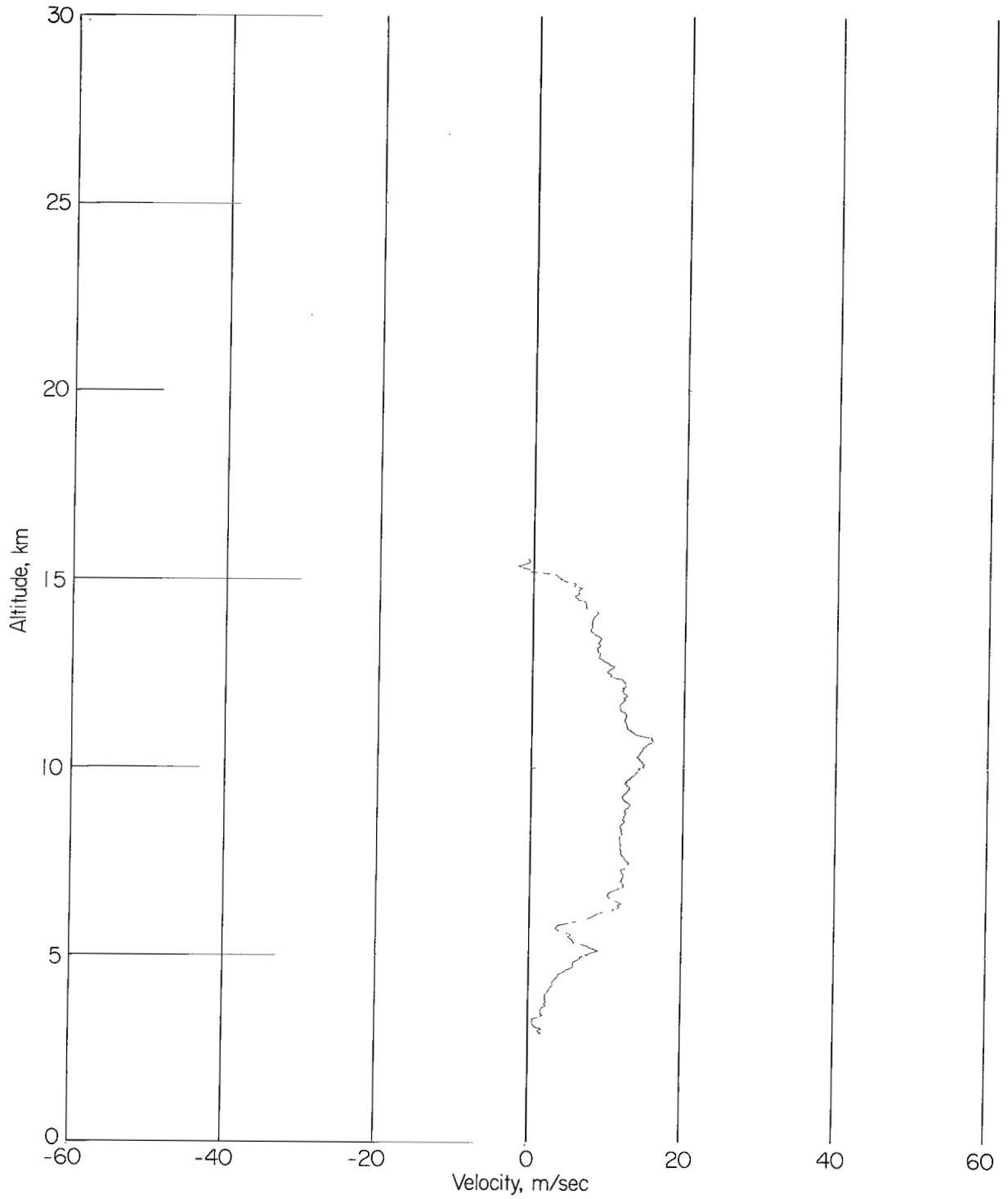
(a) West-to-east velocity component.

Figure 34.- Wind profile of smoke trail 059 obtained September 3, 1964. Time interval, 60 seconds; height interval, 25 meters.



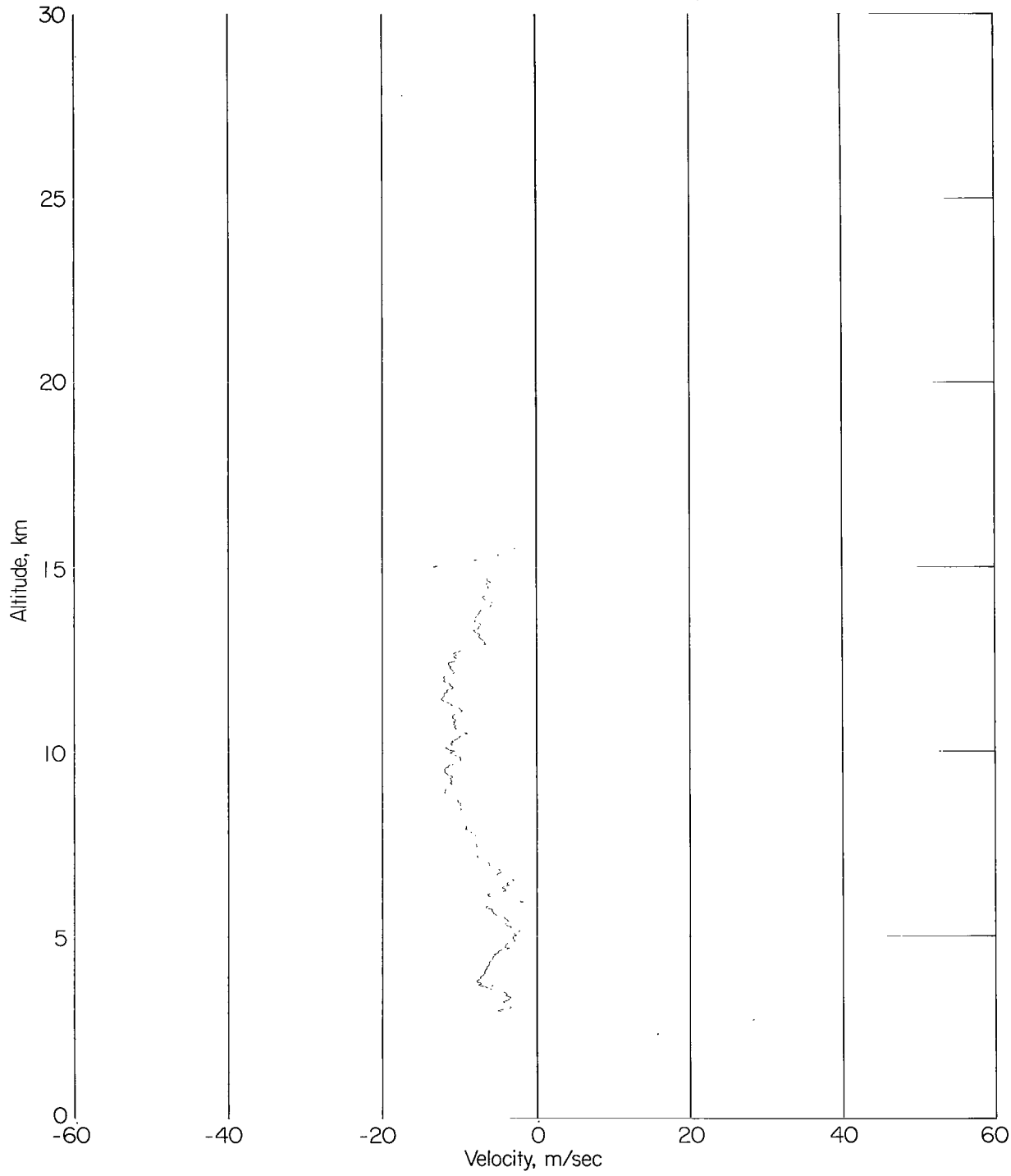
(b) South-to-north velocity component.

Figure 34.- Concluded.



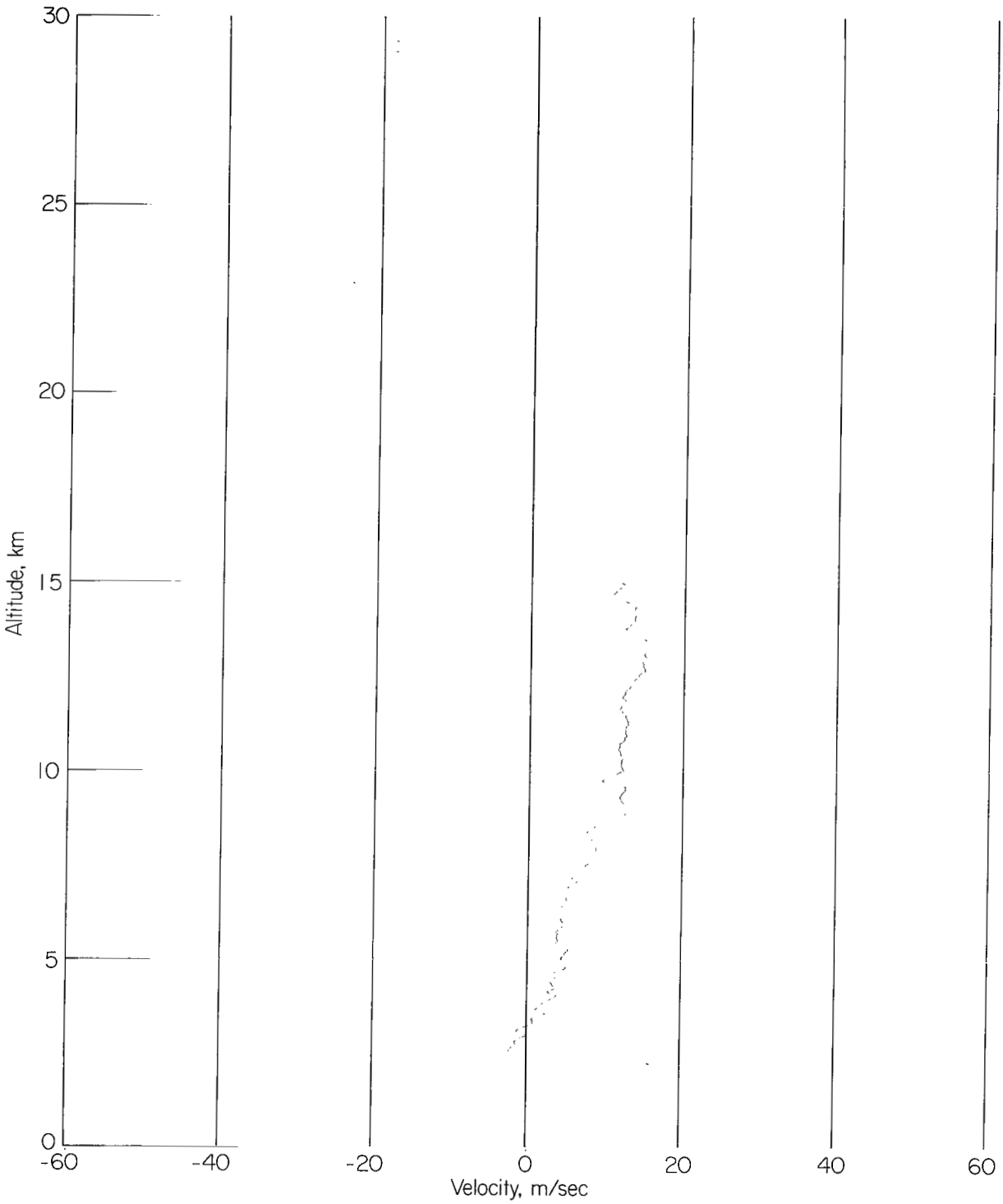
(a) West-to-east velocity component.

Figure 35.- Wind profile of smoke trail 060 obtained September 4, 1964. Time interval, 60 seconds; height interval, 25 meters.



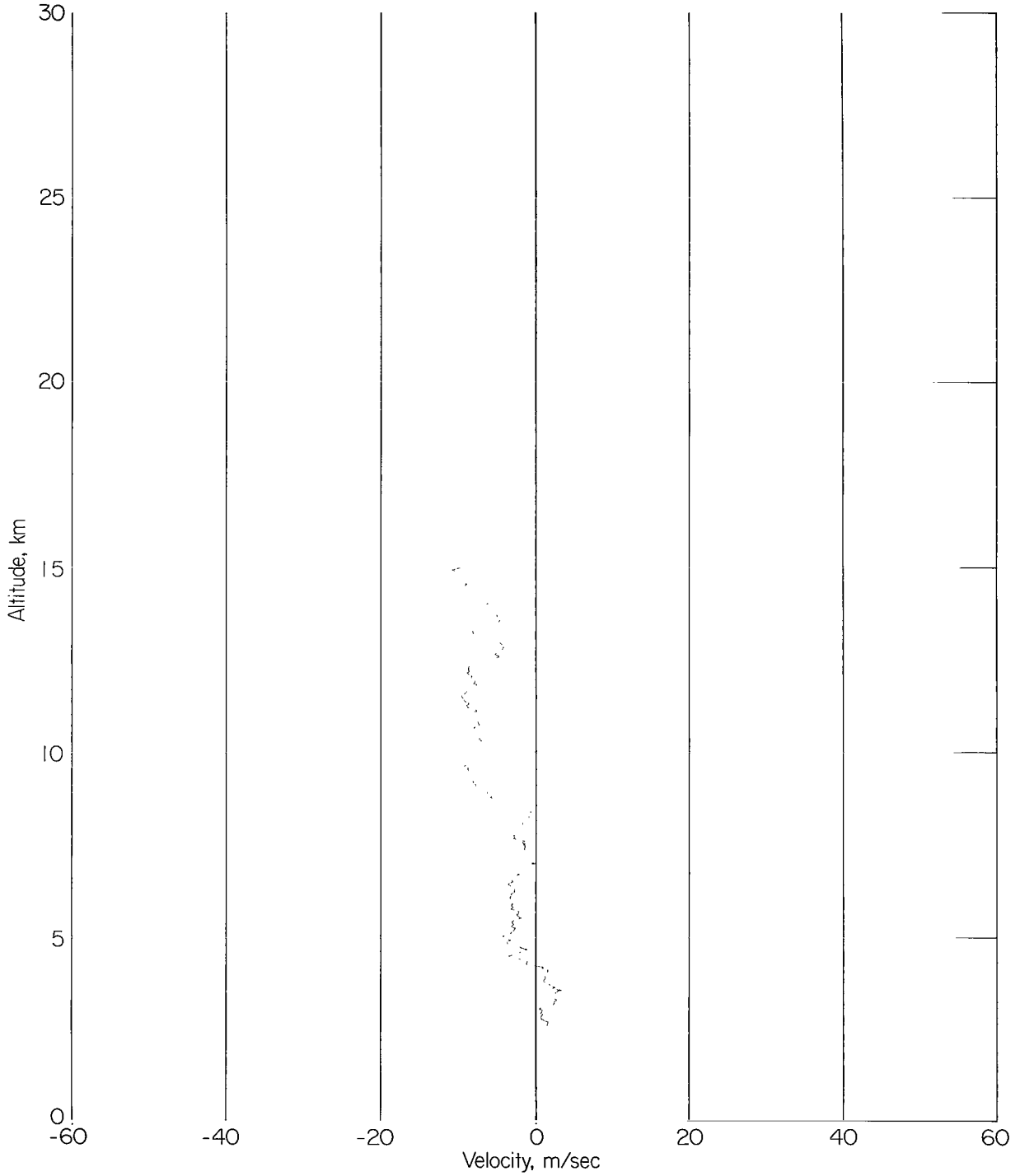
(b) South-to-north velocity component.

Figure 35.- Concluded.



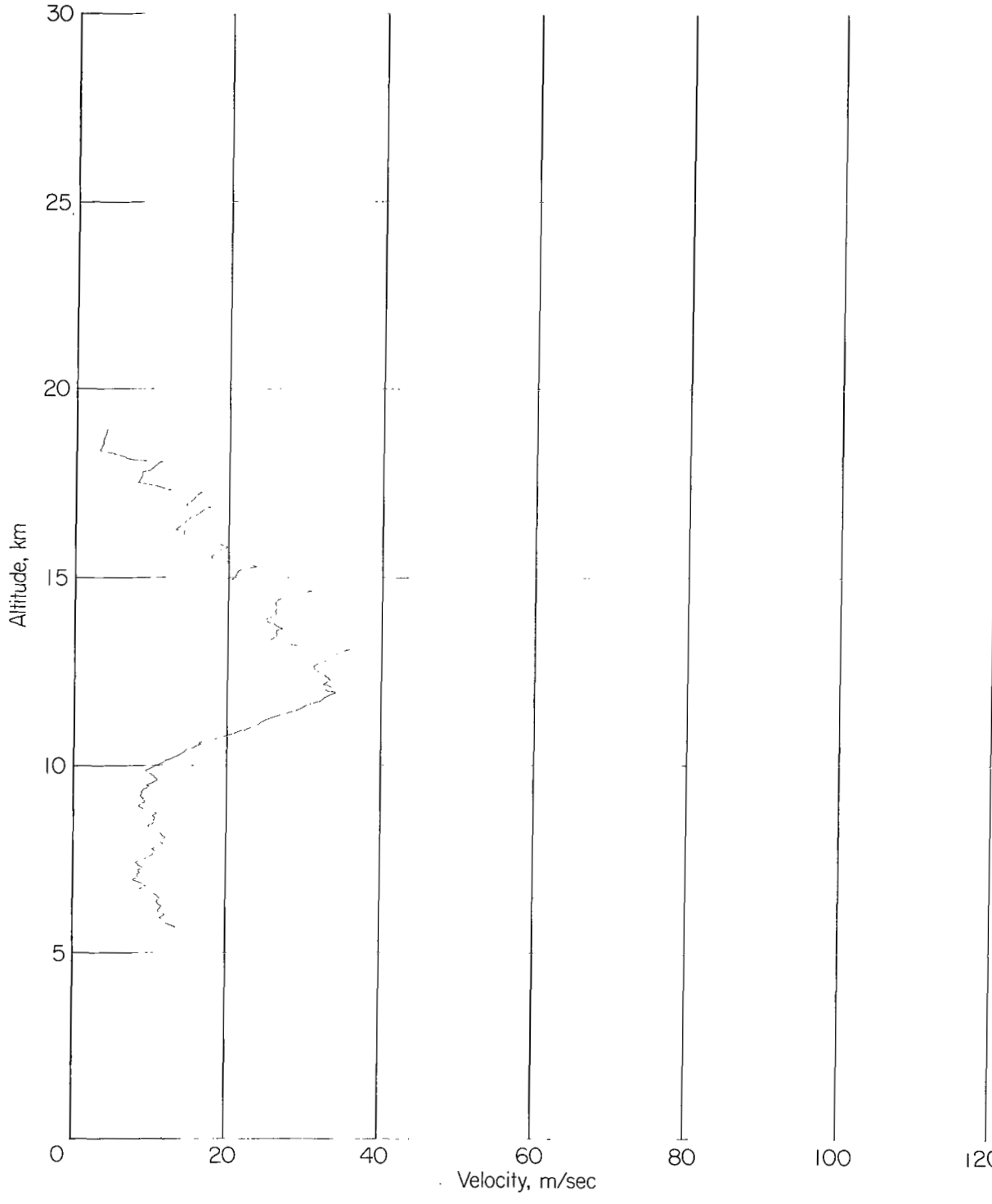
(a) West-to-east velocity component.

Figure 36.- Wind profile of smoke trail 061 obtained September 9, 1964. Time interval, 60 seconds; height interval, 25 meters.



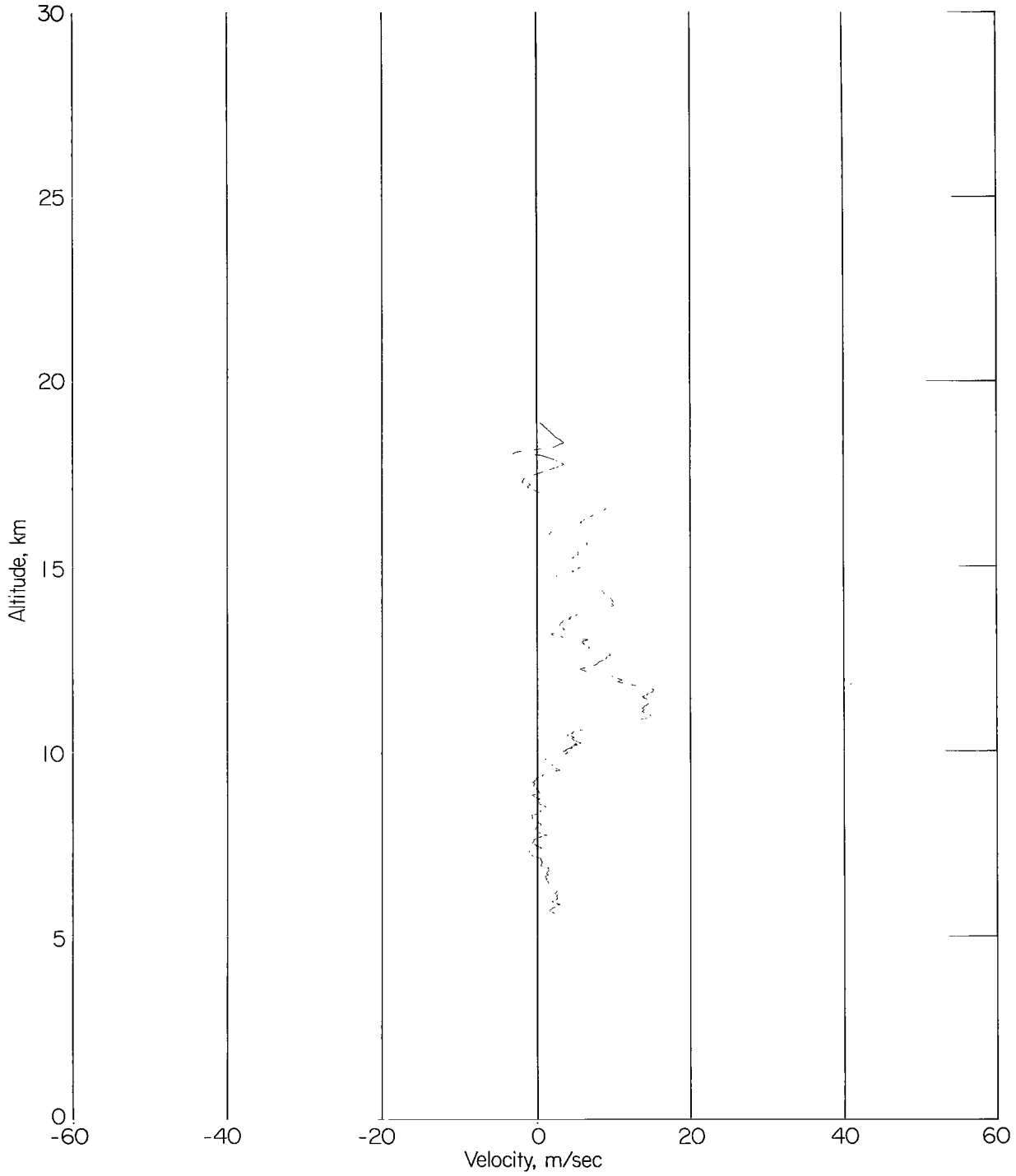
(b) South-to-north velocity component.

Figure 36.- Concluded.



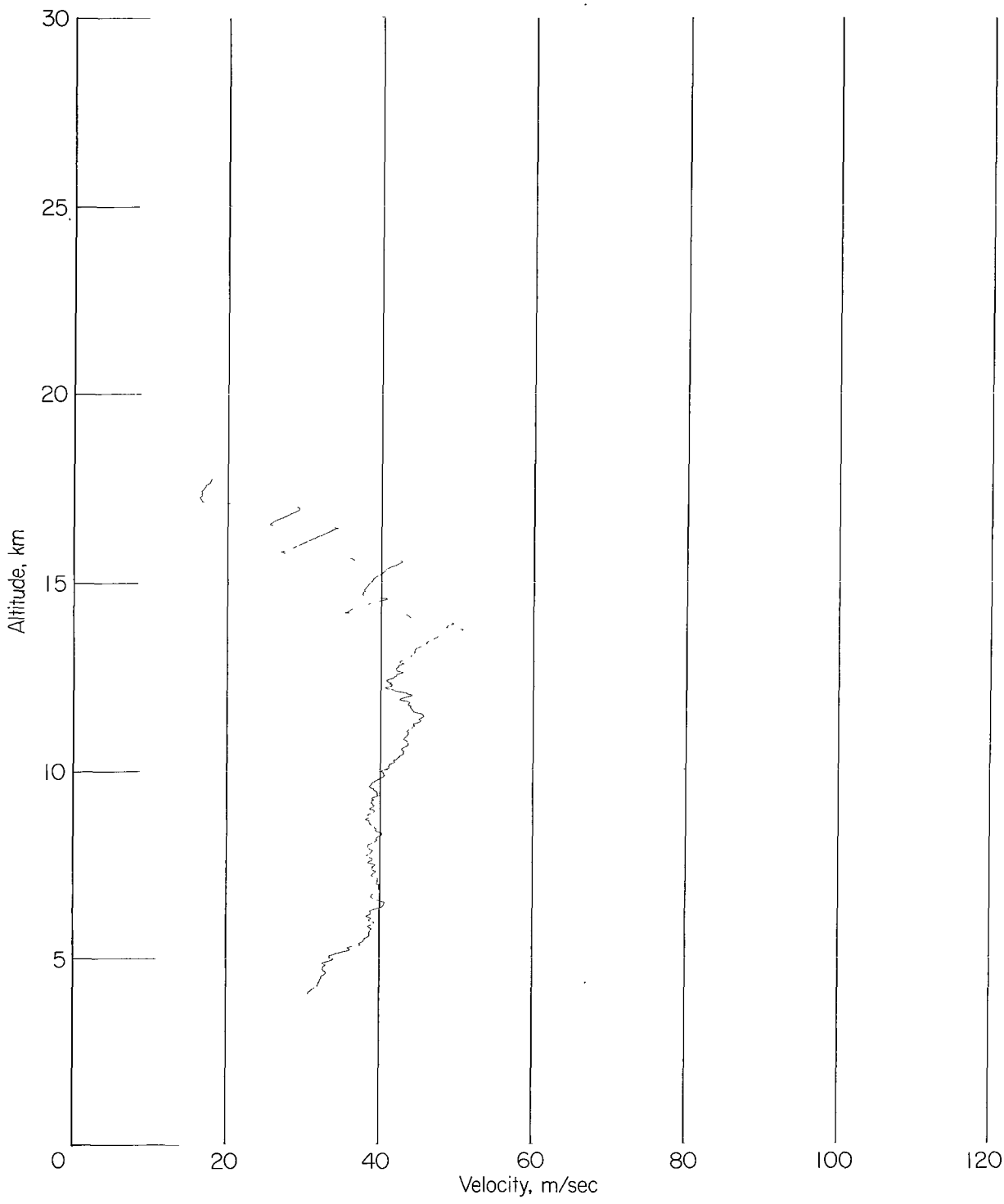
(a) West-to-east velocity component.

Figure 37.- Wind profile of smoke trail 062 obtained September 15, 1964. Time interval, 60 seconds; height interval, 25 meters.



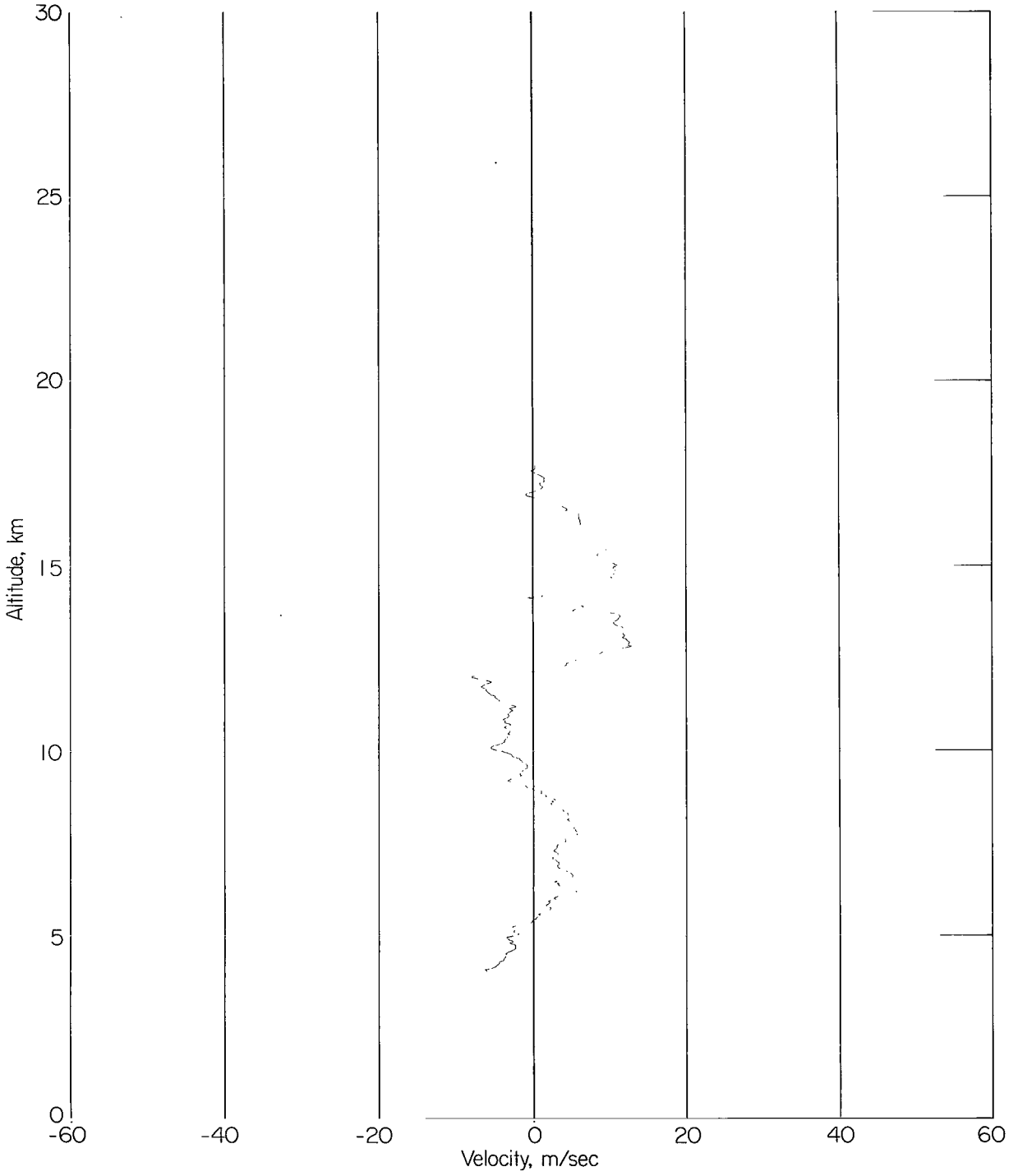
(b) South-to-north velocity component.

Figure 37.- Concluded.



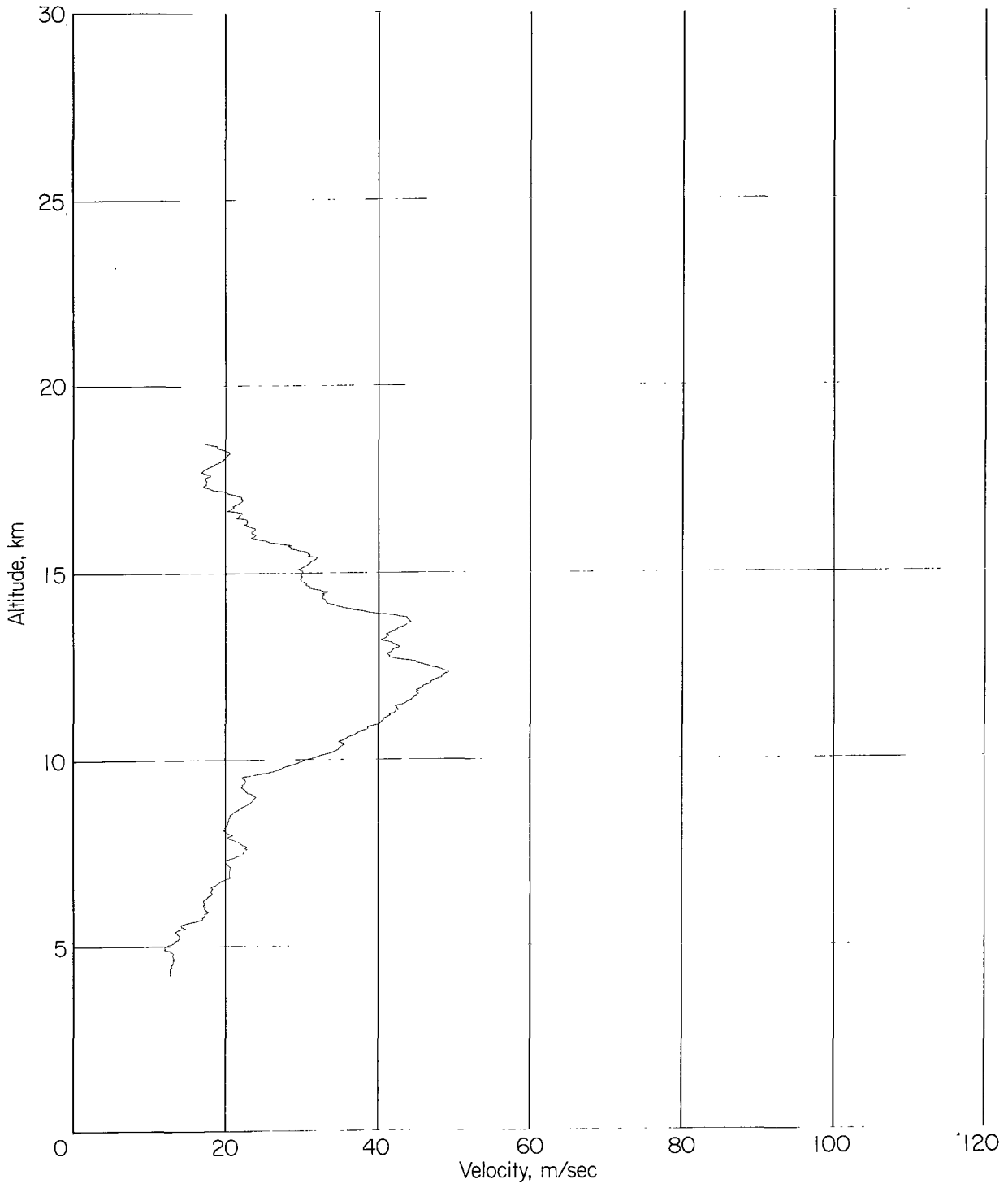
(a) West-to-east velocity component.

Figure 38.- Wind profile of smoke trail 063 obtained September 25, 1964. Time interval, 60 seconds; height interval, 25 meters.



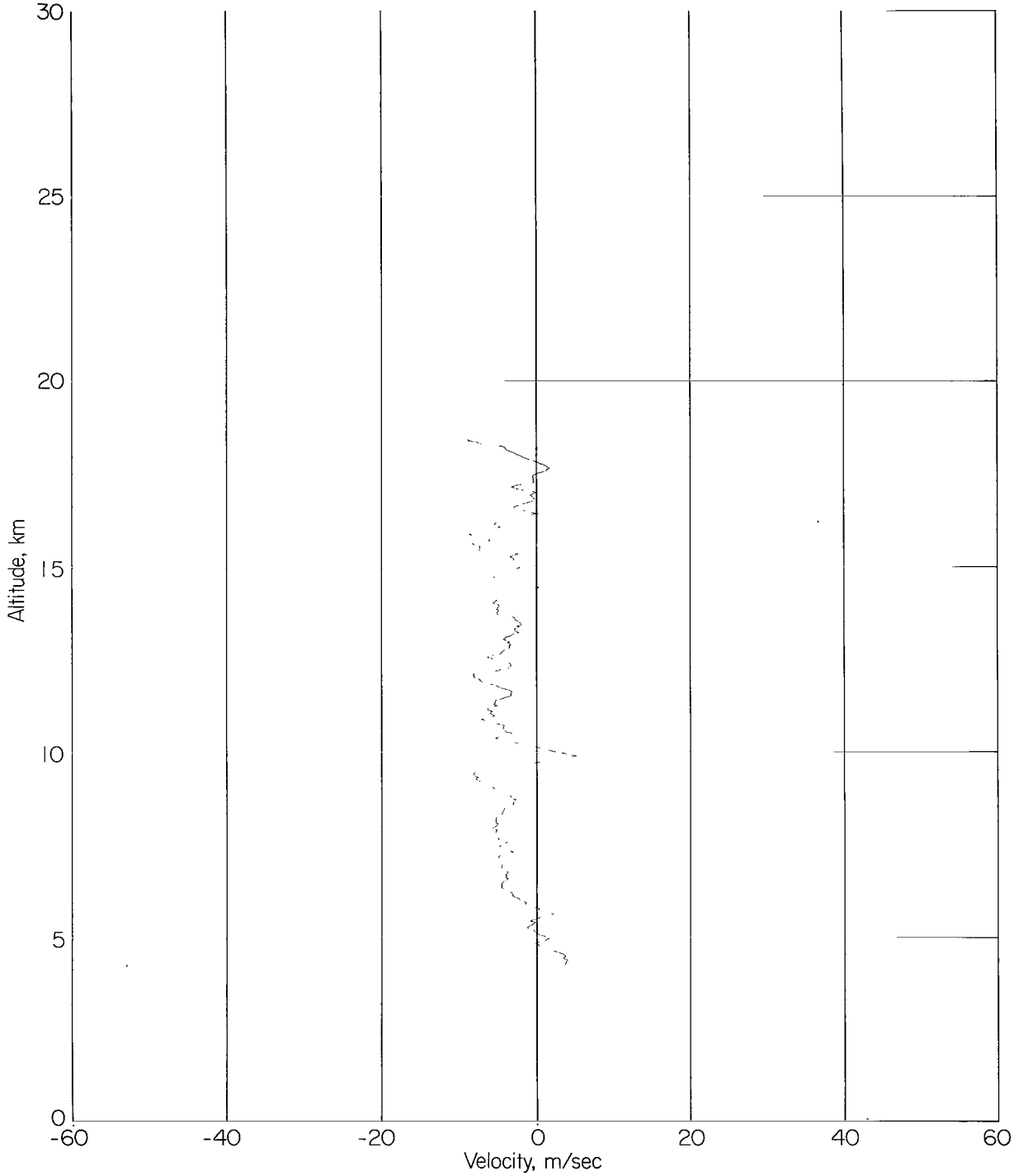
(b) South-to-north velocity component.

Figure 38.- Concluded.



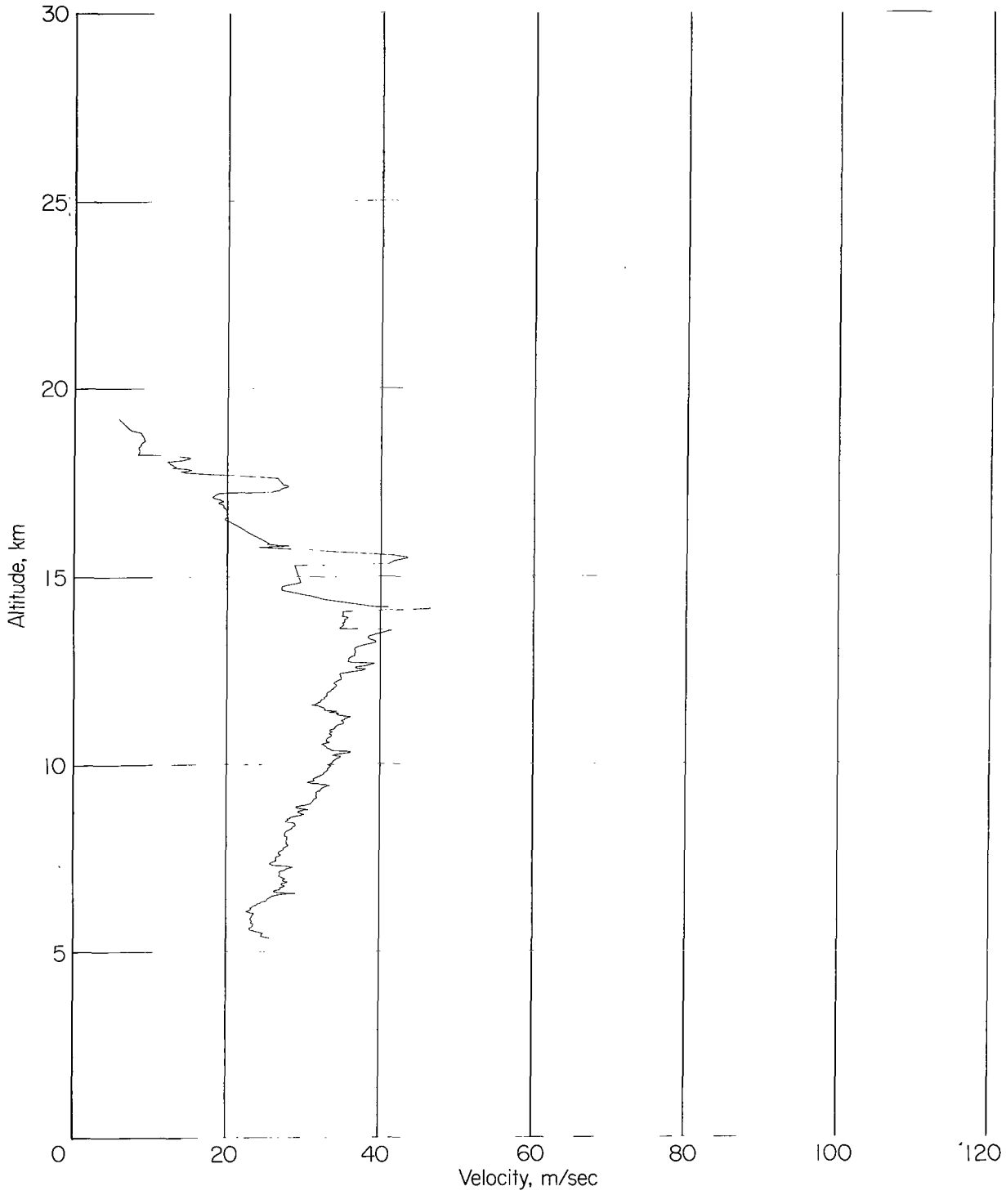
(a) West-to-east velocity component.

Figure 39.- Wind profile of smoke trail 064 obtained October 13, 1964. Time interval, 60 seconds; height interval, 25 meters.



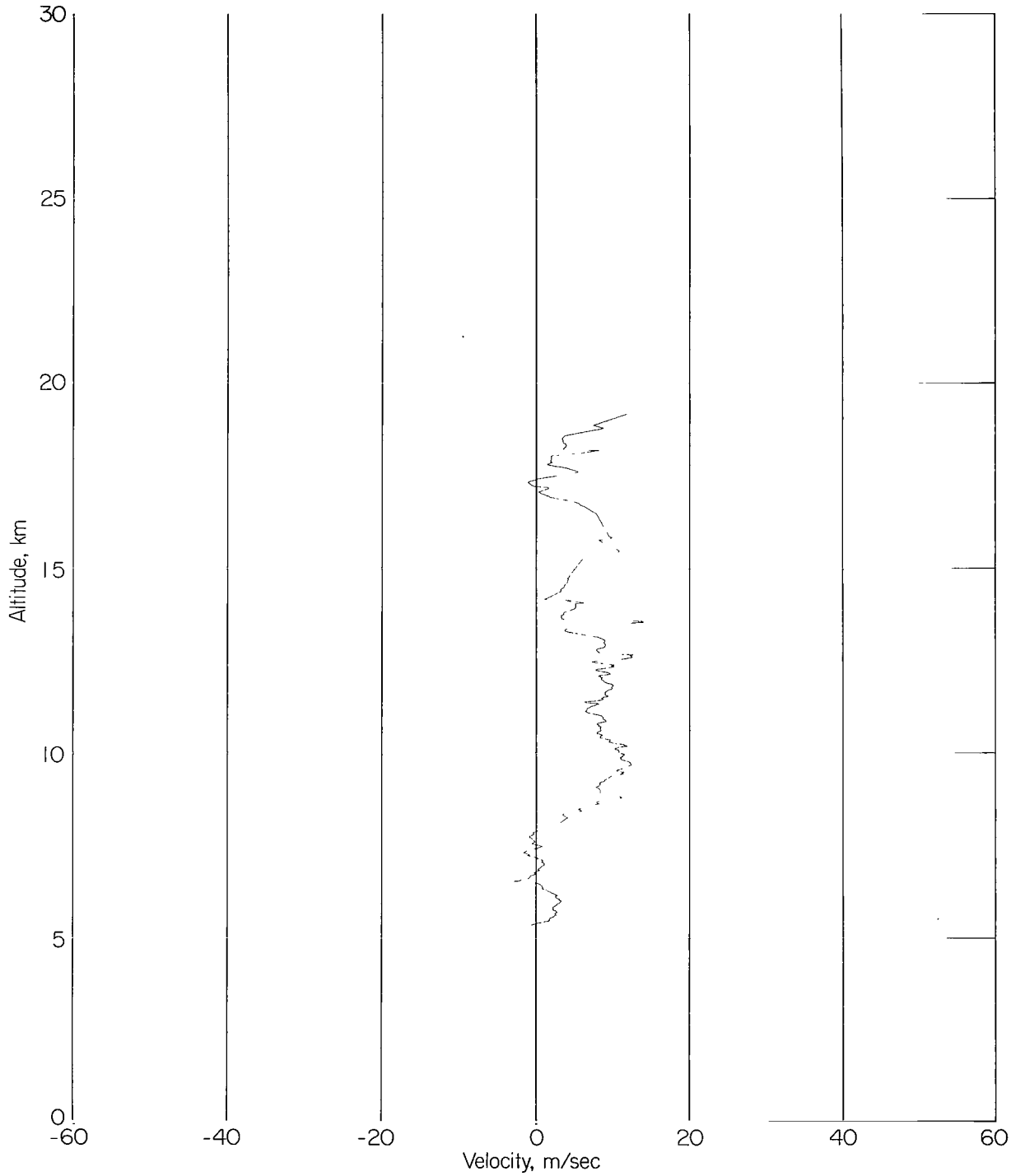
(b) South-to-north velocity component.

Figure 39.- Concluded.



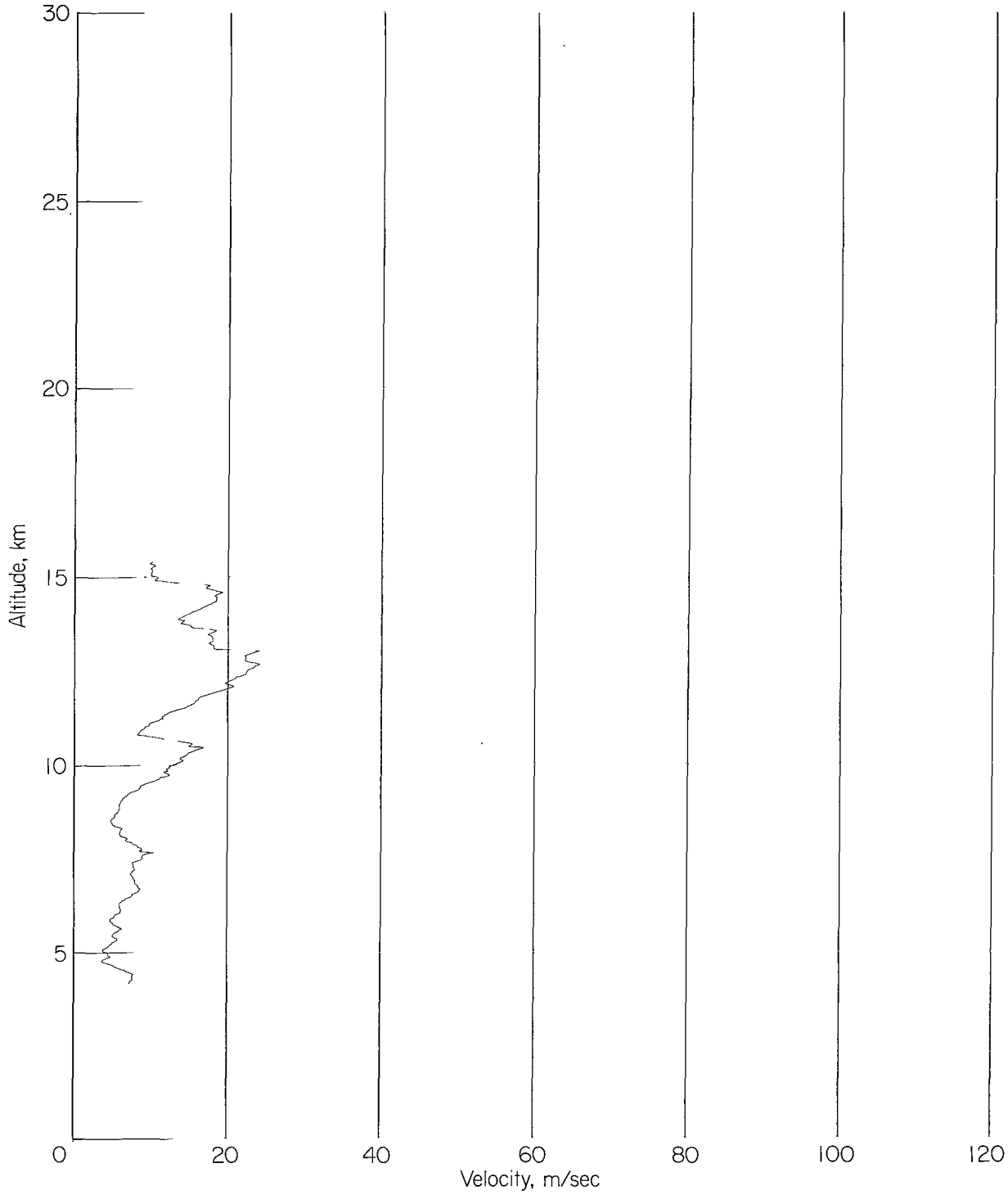
(a) West-to-east velocity component.

Figure 40.- Wind profile of smoke trail 065 obtained October 22, 1964. Time interval, 60 seconds; height interval, 25 meters.



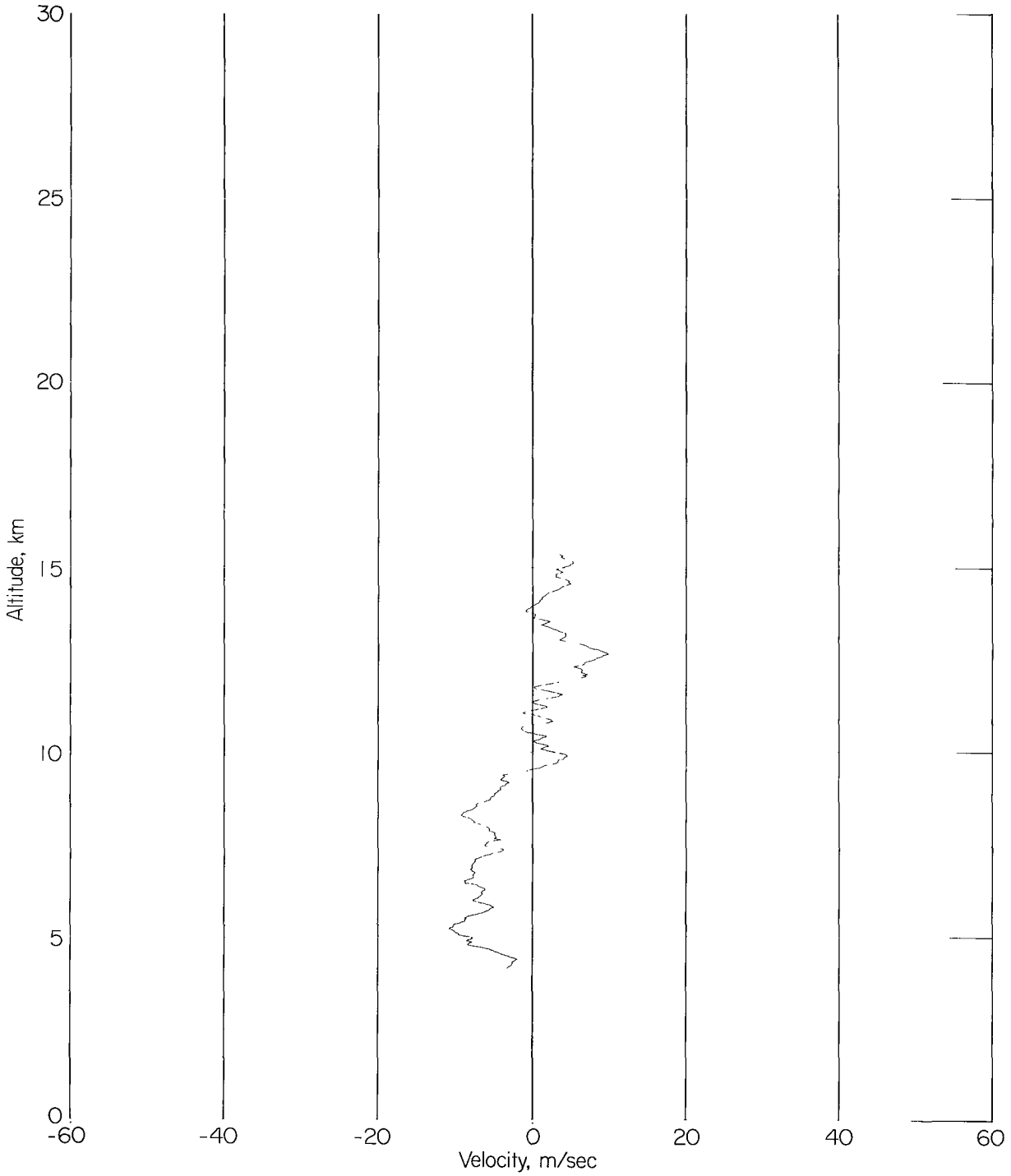
(b) South-to-north velocity component.

Figure 40.- Concluded.



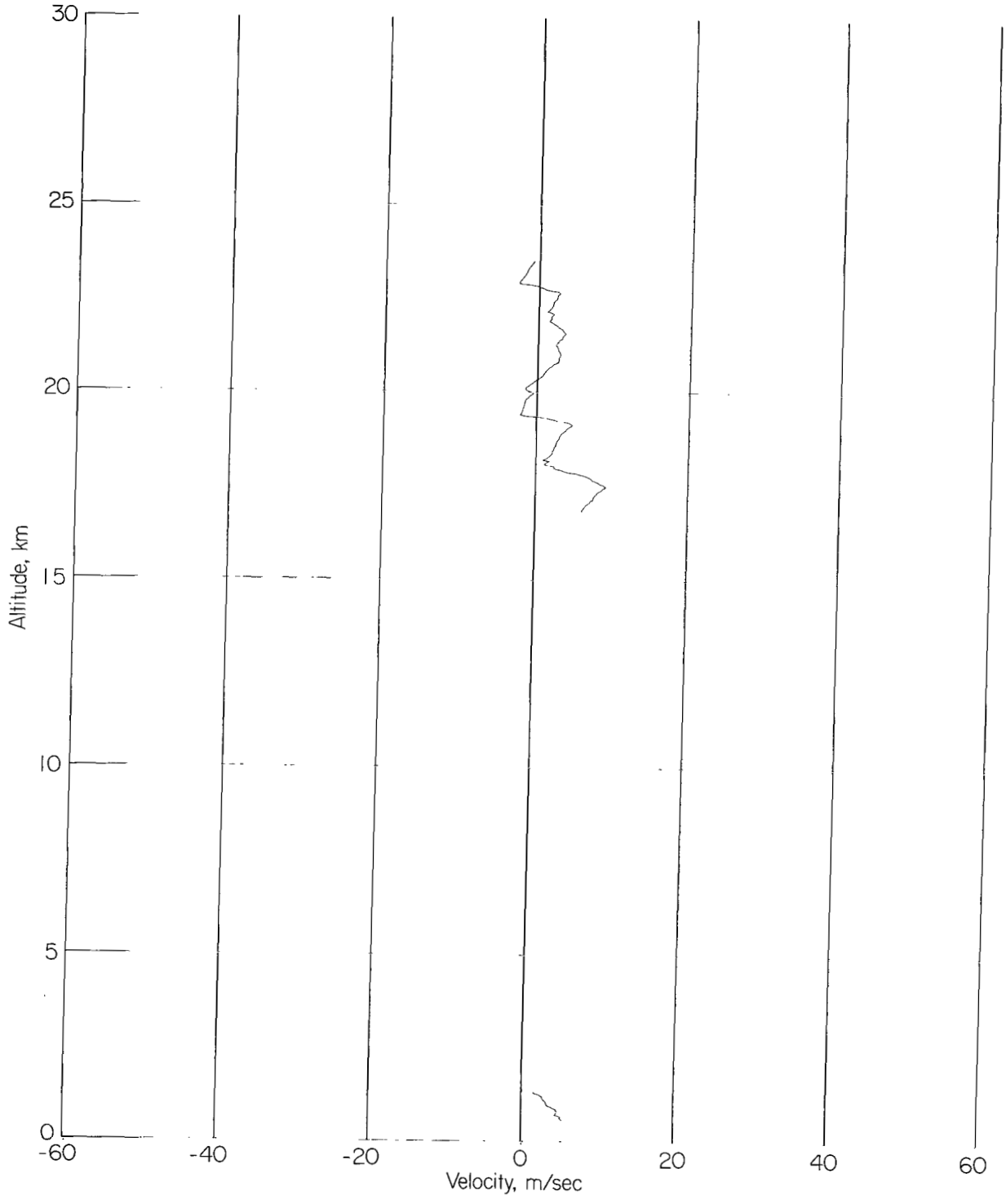
(a) West-to-east velocity component.

Figure 41.- Wind profile of smoke trail 066 obtained October 30, 1964. Time interval, 60 seconds; height interval, 25 meters.



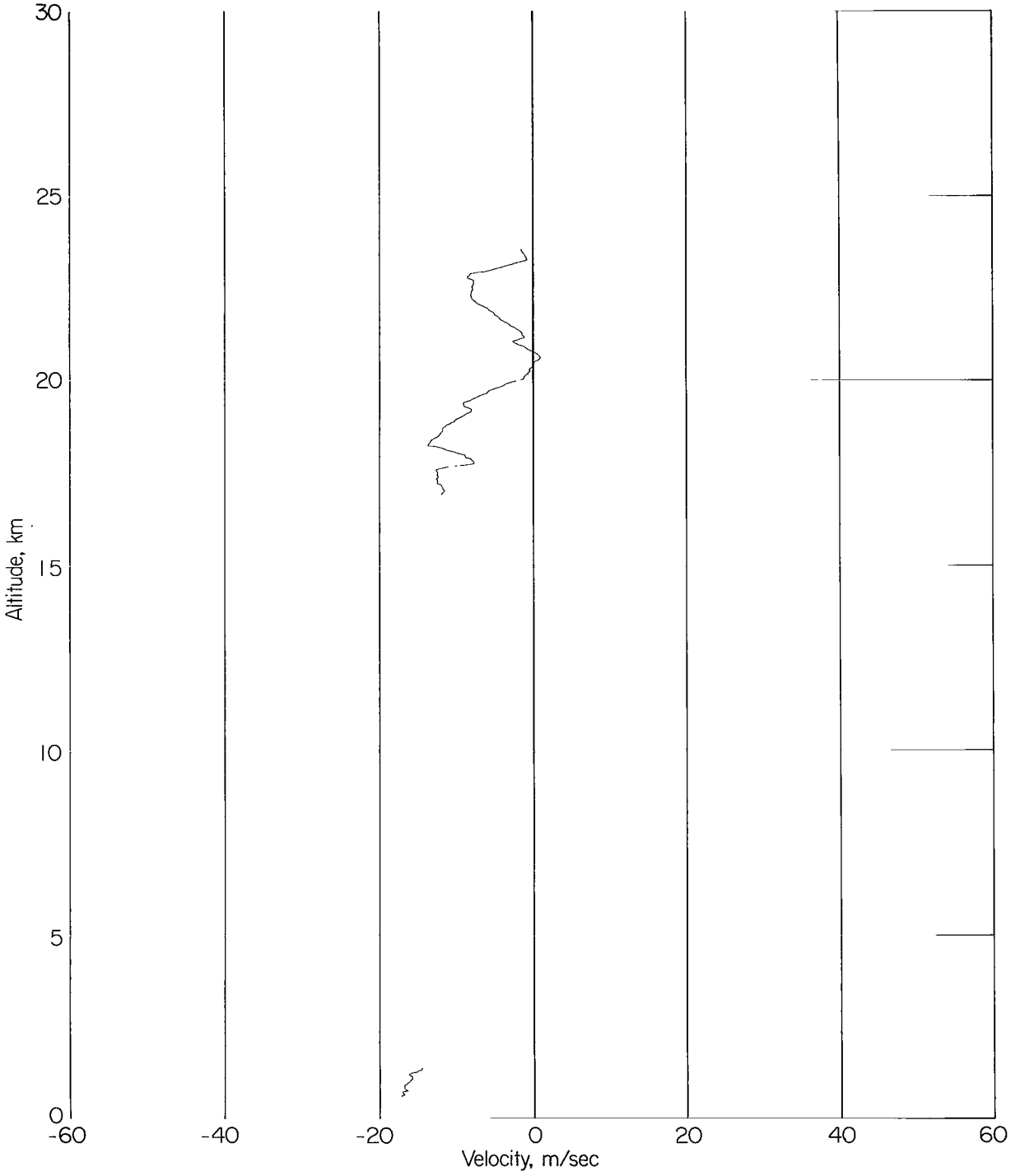
(b) South-to-north velocity component.

Figure 41.- Concluded.



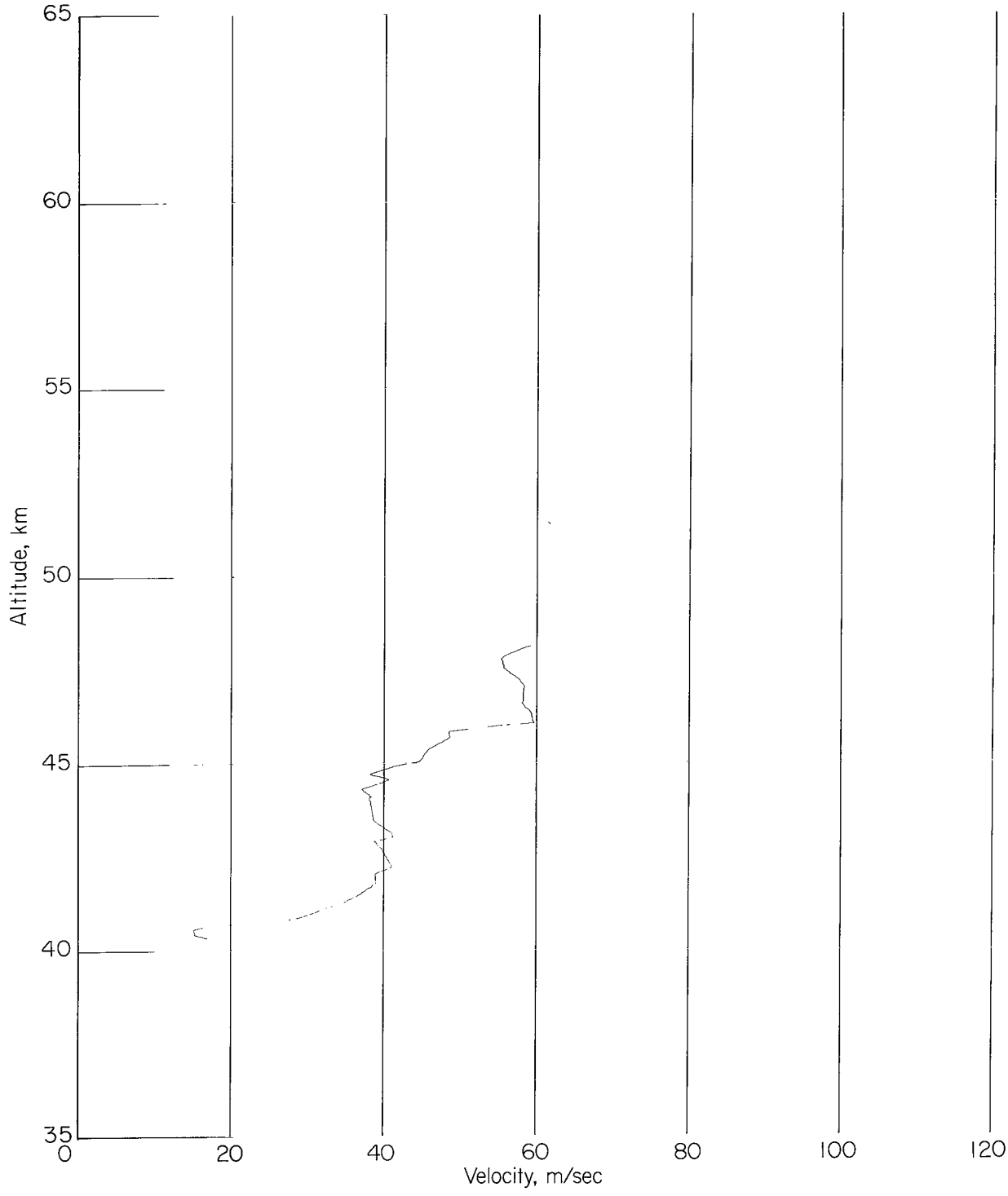
(a) First-stage west-to-east velocity component. Time interval, 60 seconds.

Figure 42.- Wind profile of smoke trail 067 obtained November 6, 1964. Height interval, 25 meters.



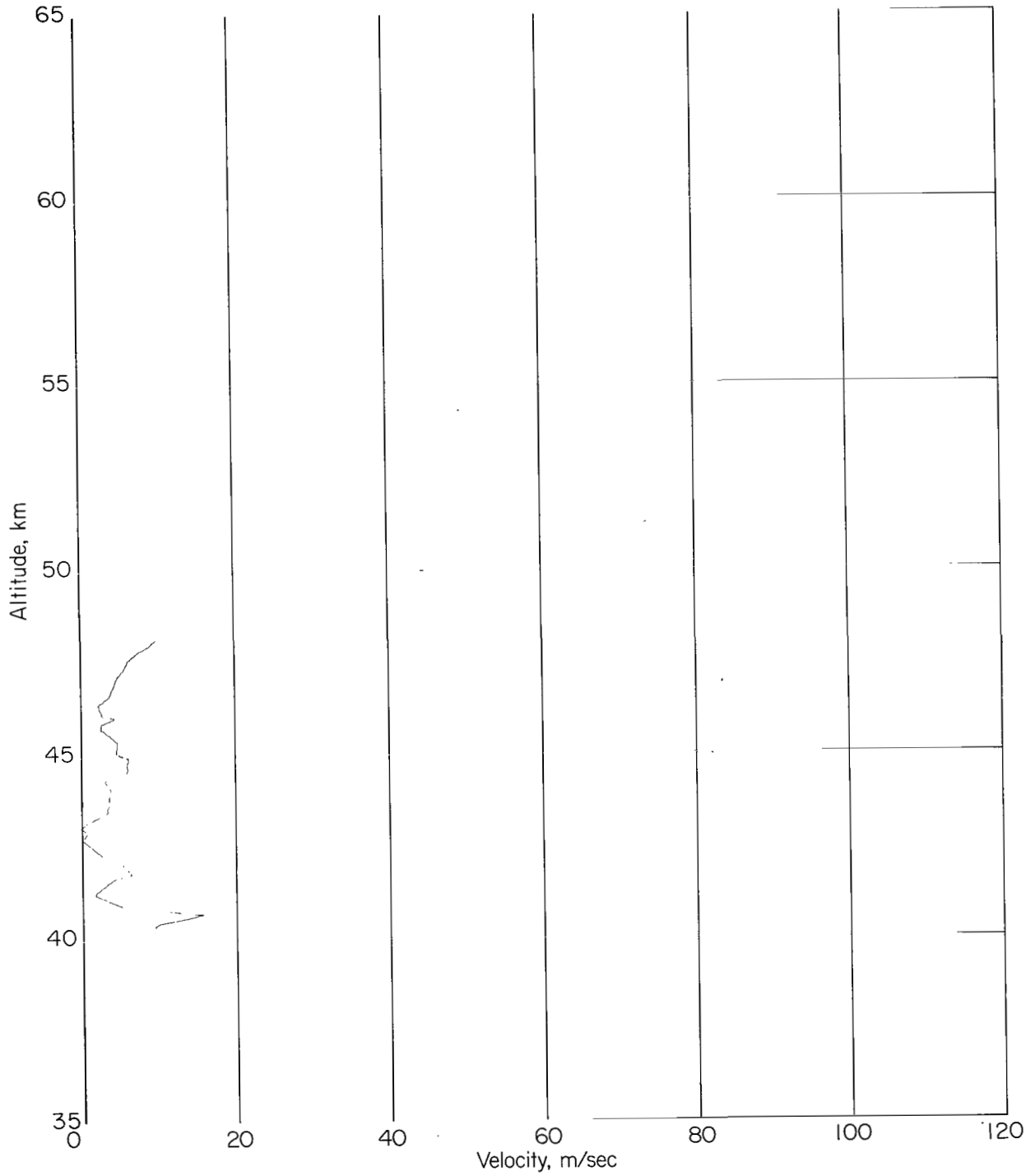
(b) First-stage south-to-north velocity component. Time interval, 60 seconds.

Figure 42.- Continued.



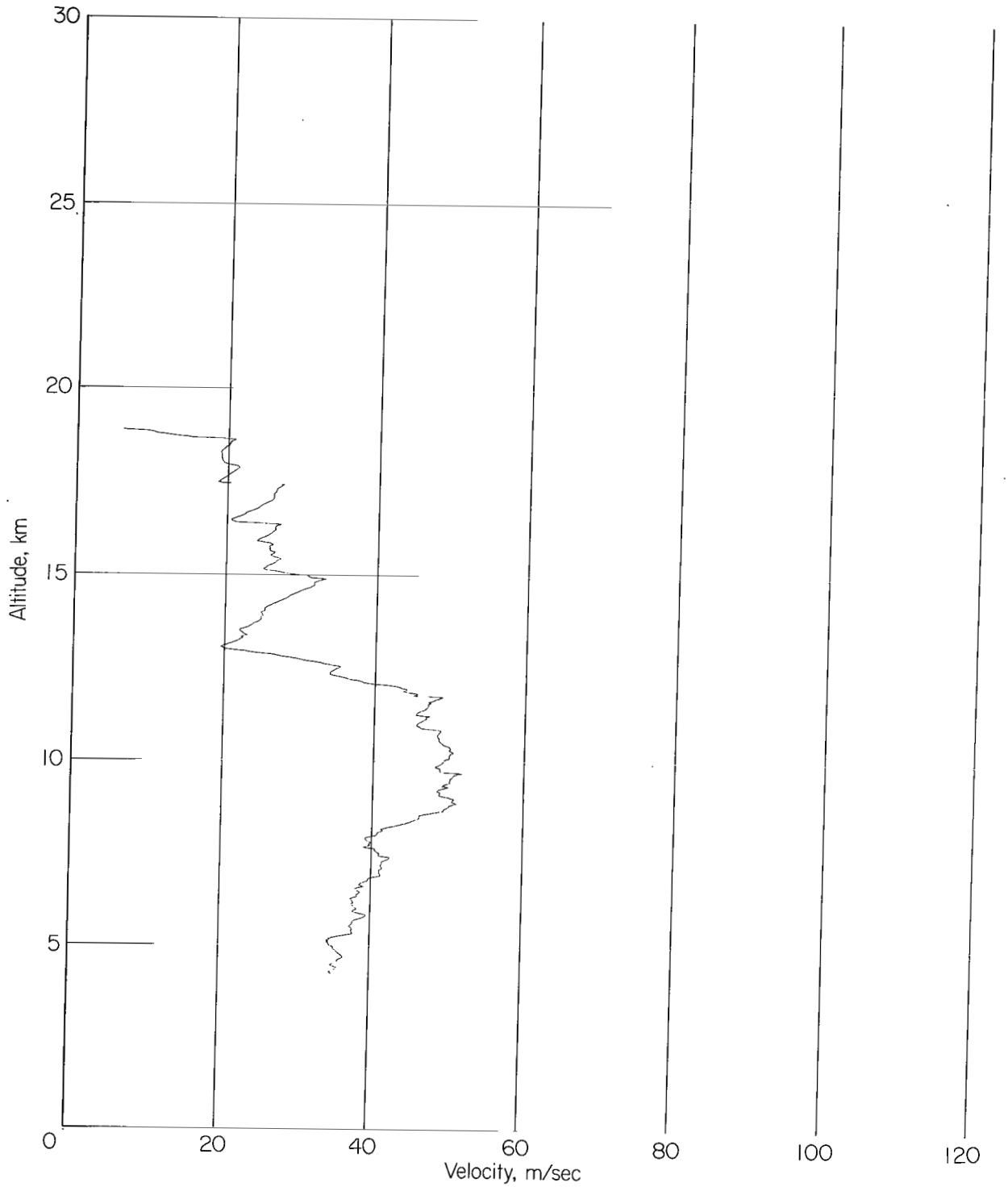
(c) Second-stage west-to-east velocity component. Time interval, 30 seconds.

Figure 42.- Continued.



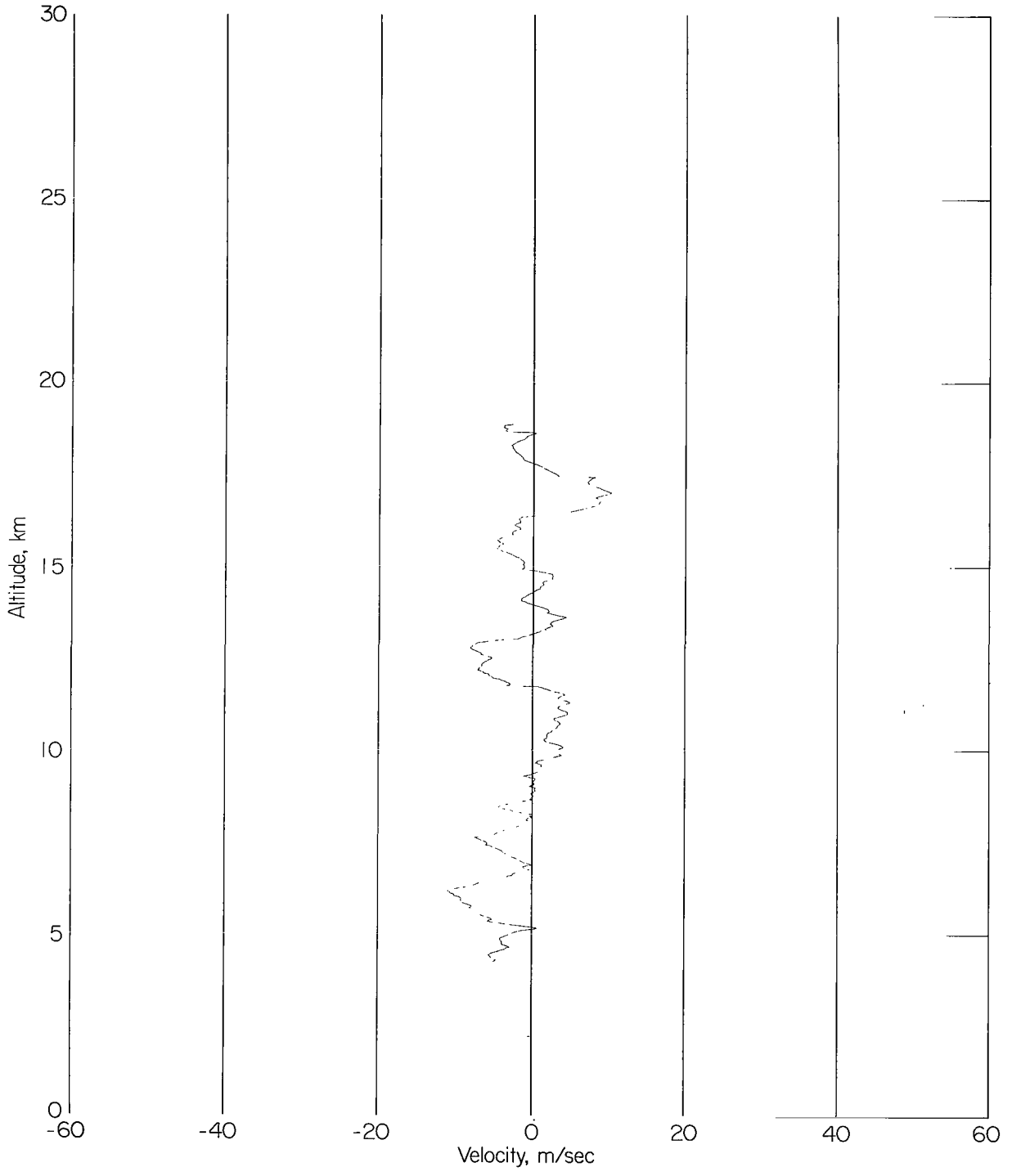
(d) Second-stage south-to-north velocity component. Time interval, 30 seconds.

Figure 42.- Concluded.



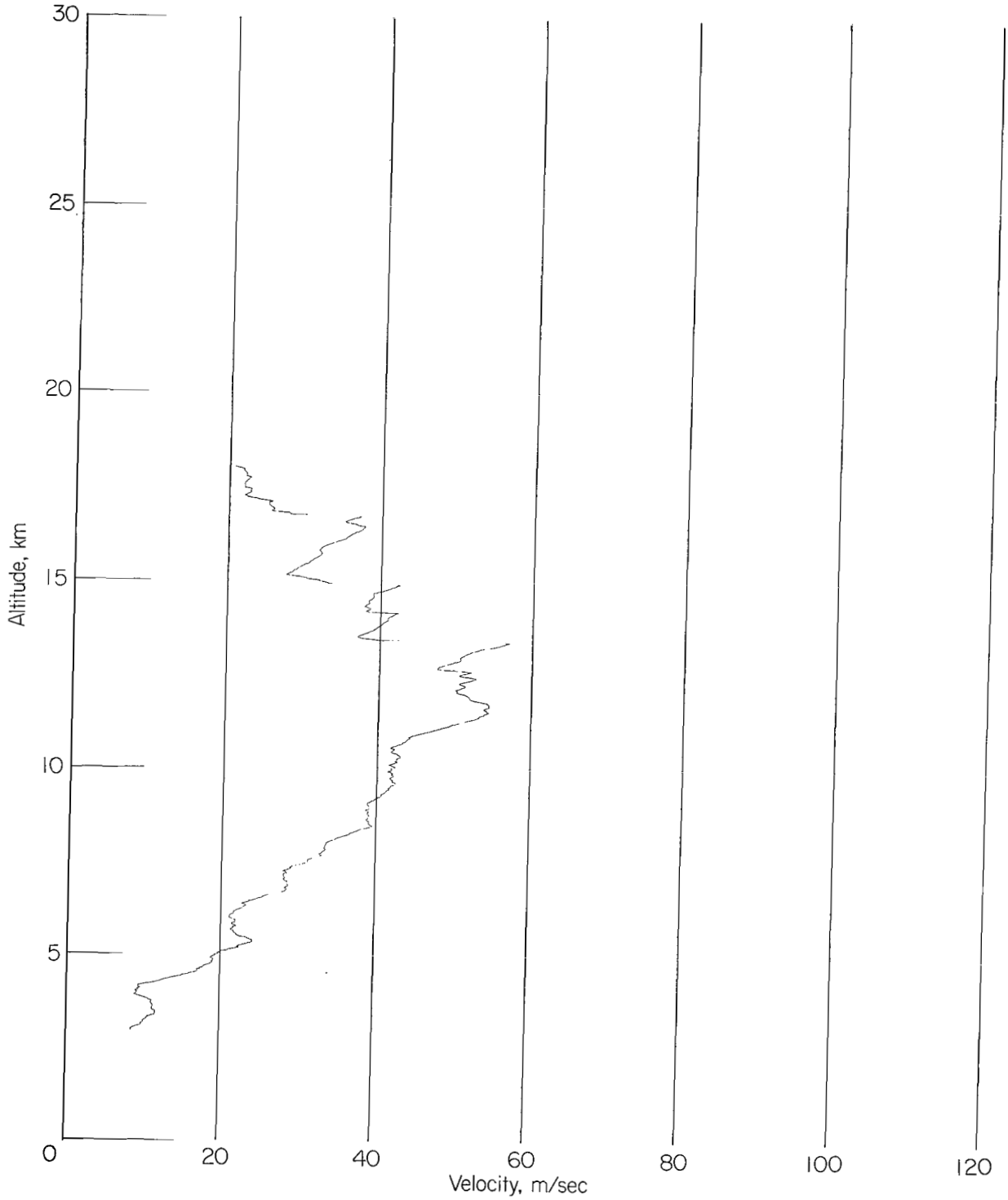
(a) West-to-east velocity component.

Figure 43.- Wind profile of smoke trail 068 obtained November 13, 1964. Time interval, 60 seconds; height interval, 25 meters.



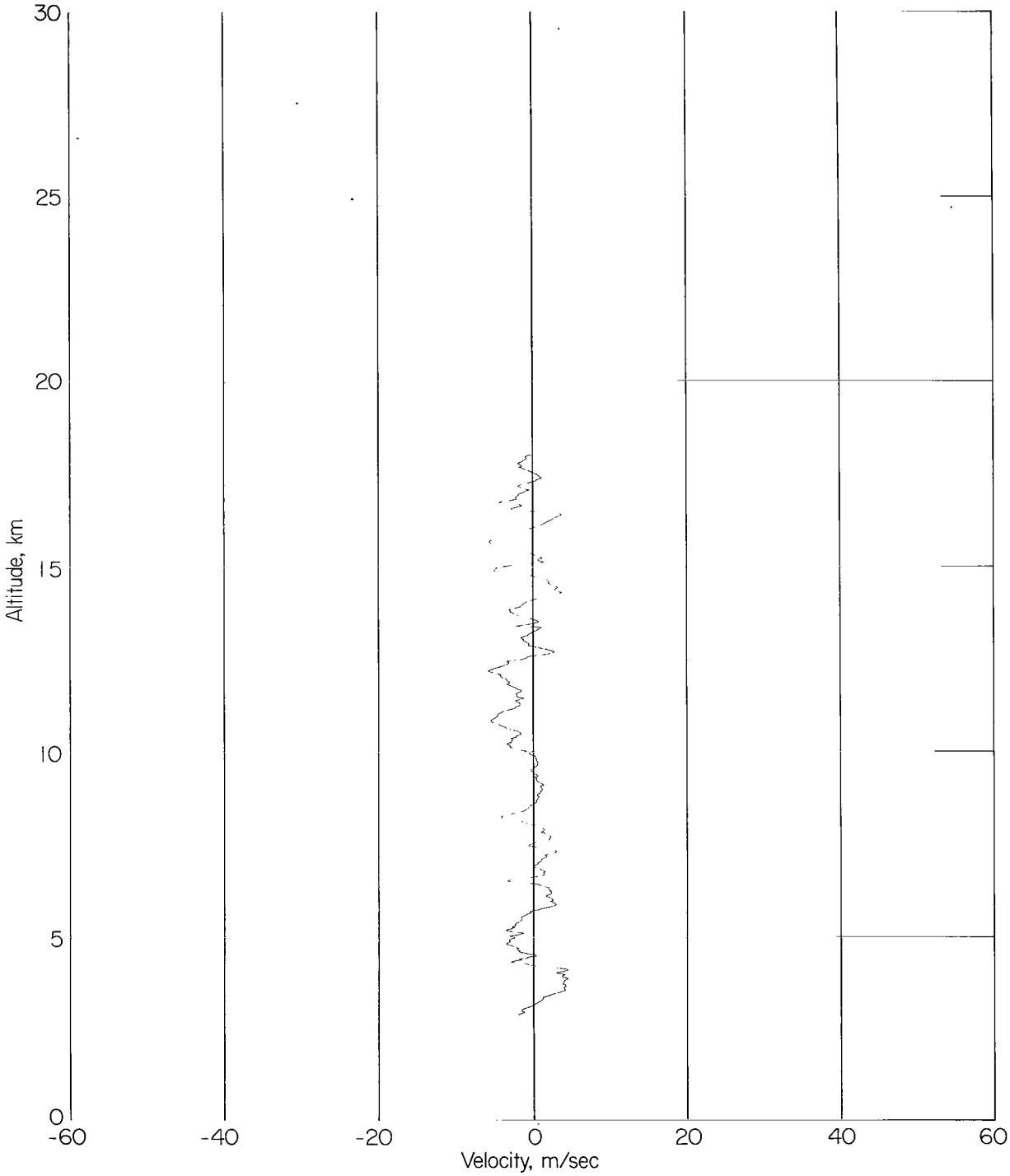
(b) South-to-north velocity component.

Figure 43.- Concluded.



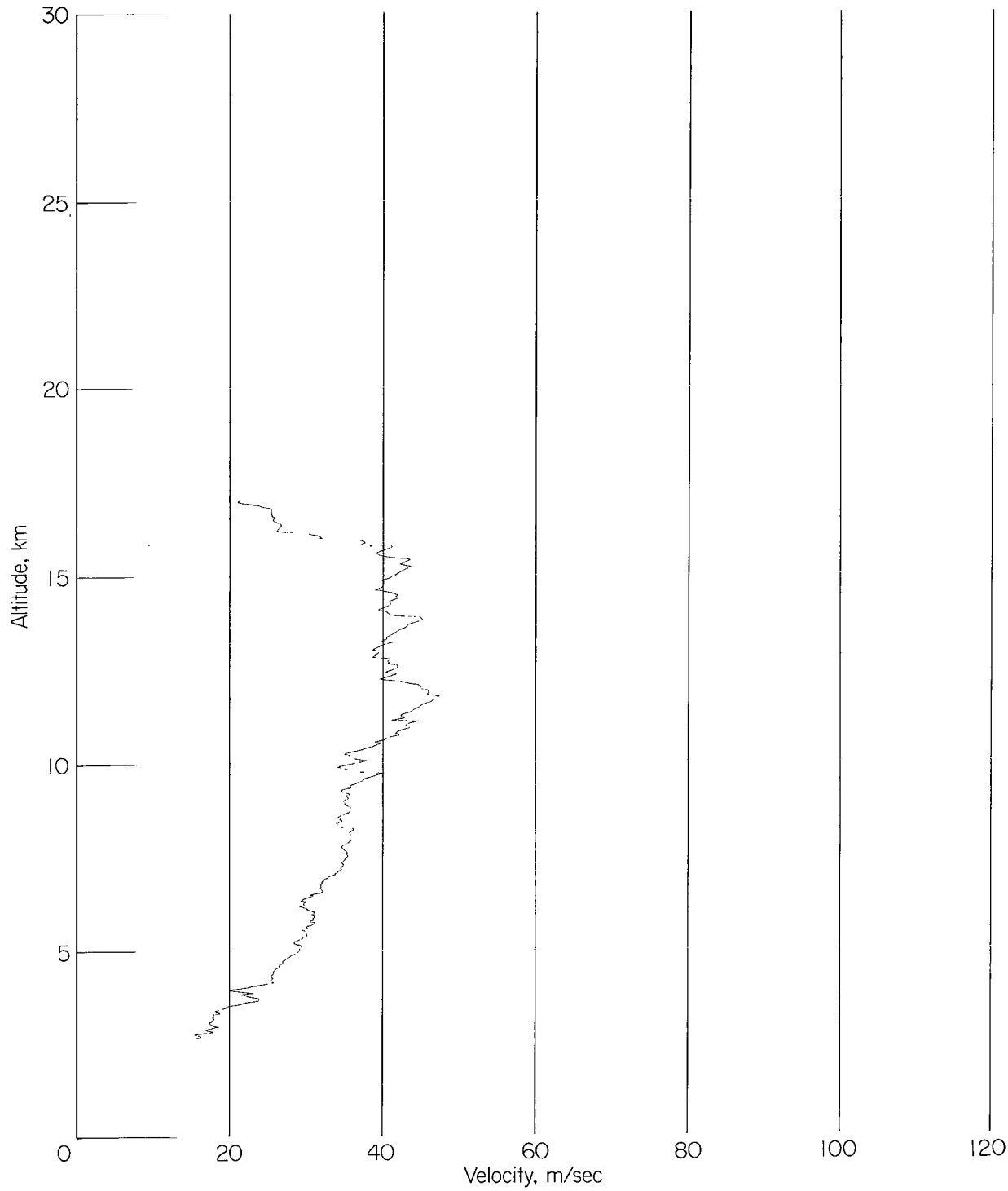
(a) West-to-east velocity component.

Figure 44.- Wind profile of smoke trail 069 obtained November 24, 1964. Time interval, 60 seconds; height interval, 25 meters.



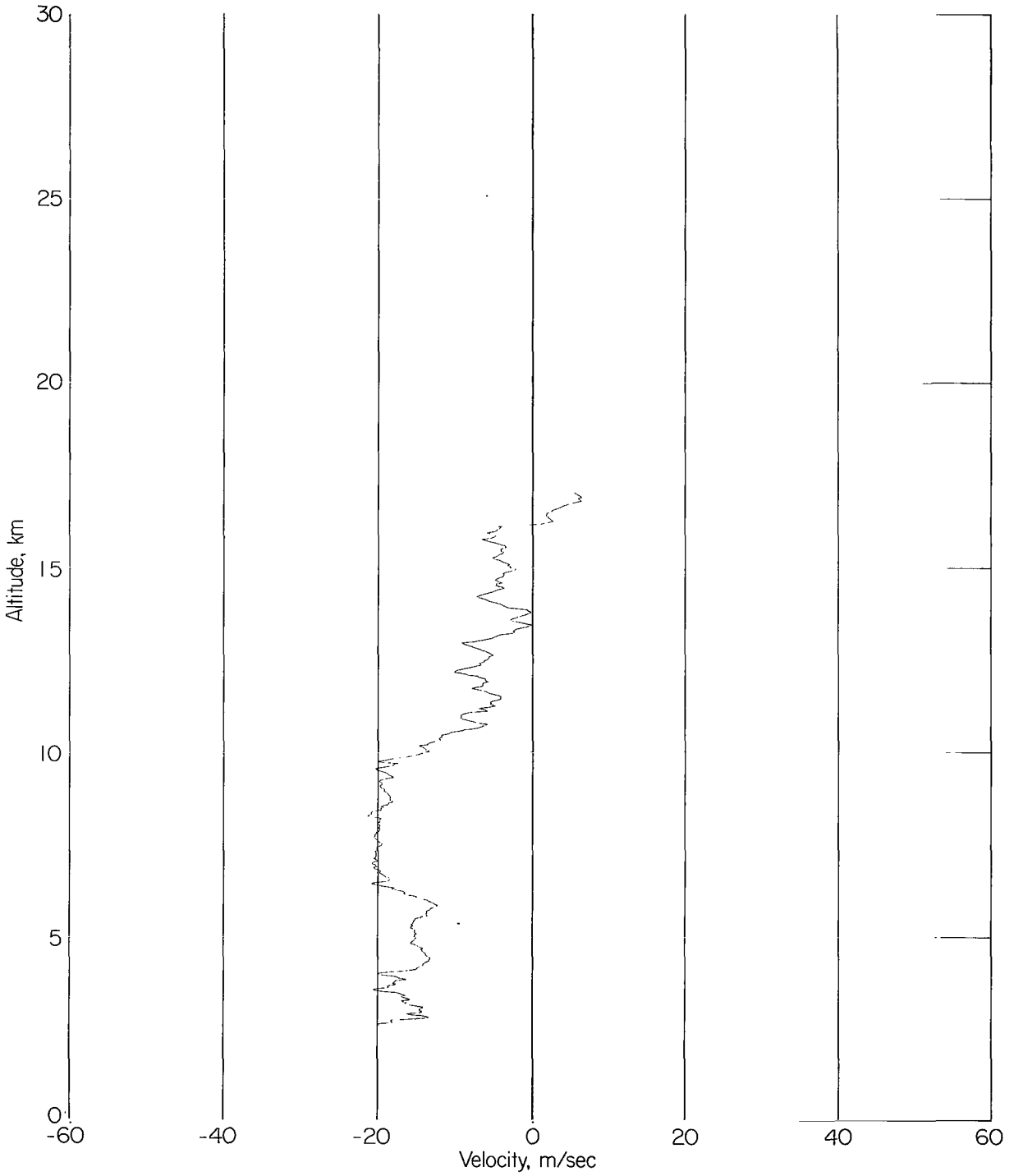
(b) South-to-north velocity component.

Figure 44.- Concluded.



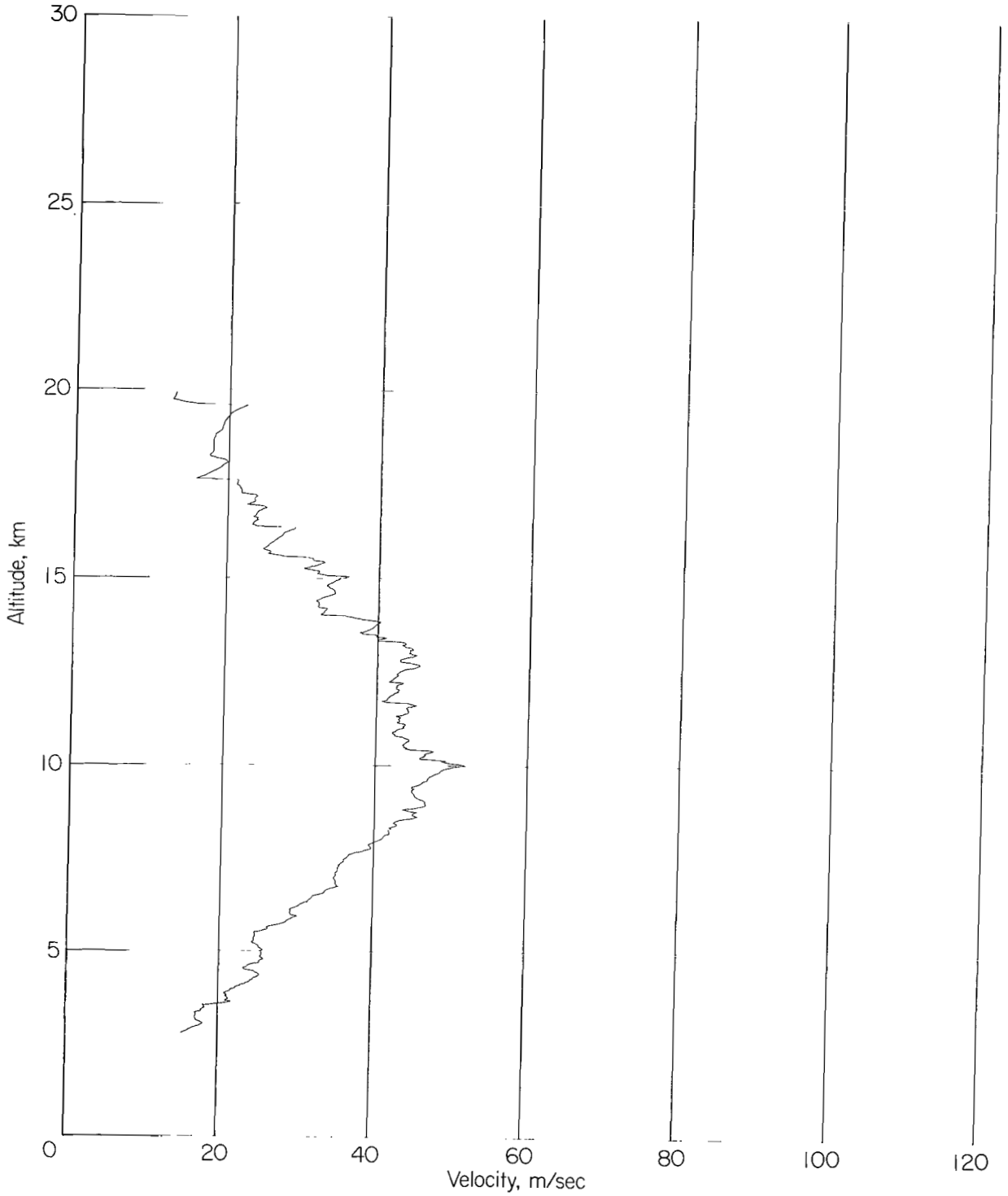
(a) West-to-east velocity component.

Figure 45.- Wind profile of smoke trail 070 obtained December 1, 1964. Time interval, 60 seconds; height interval, 25 meters.



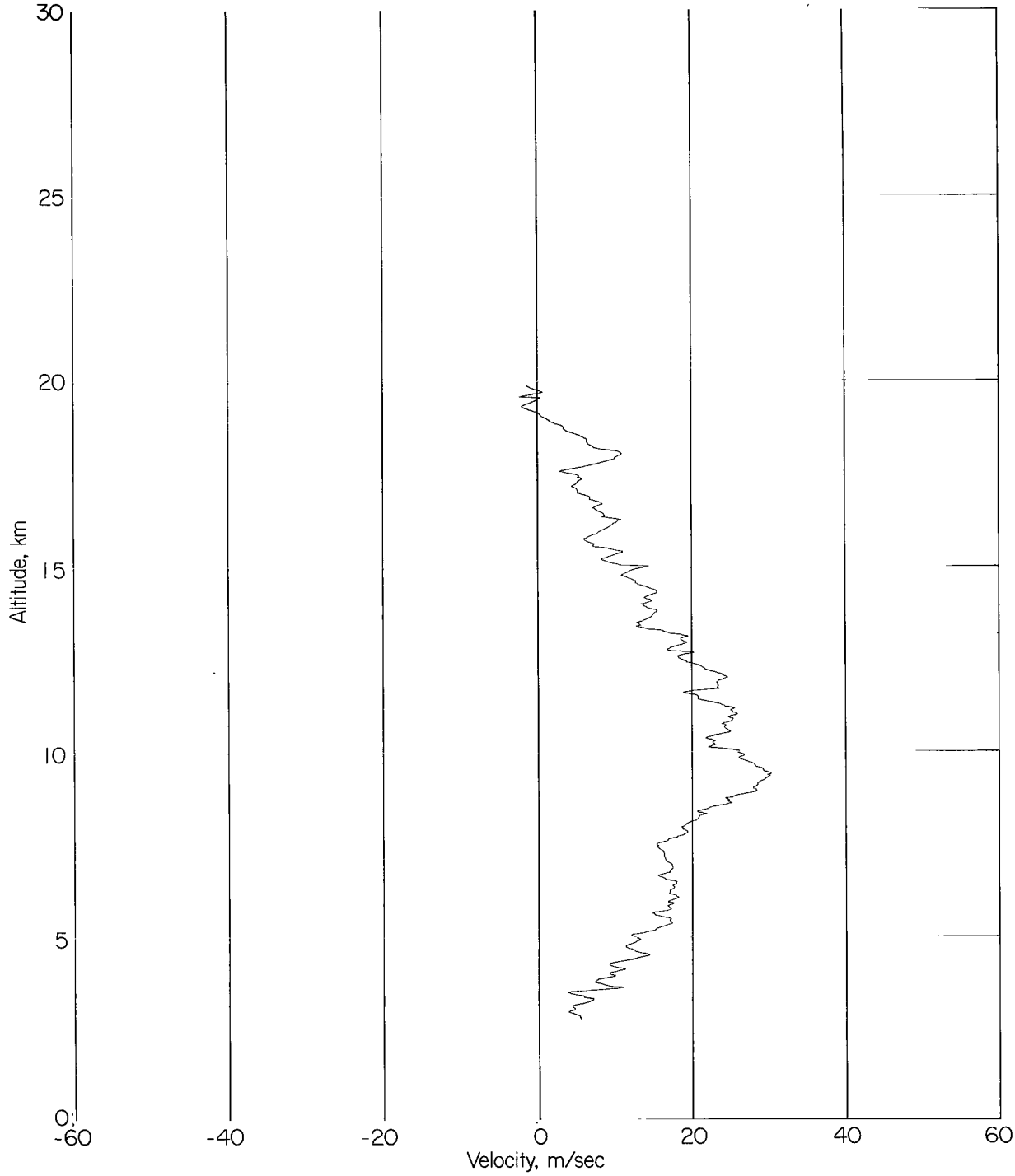
(b) South-to-north velocity component.

Figure 45.- Concluded.



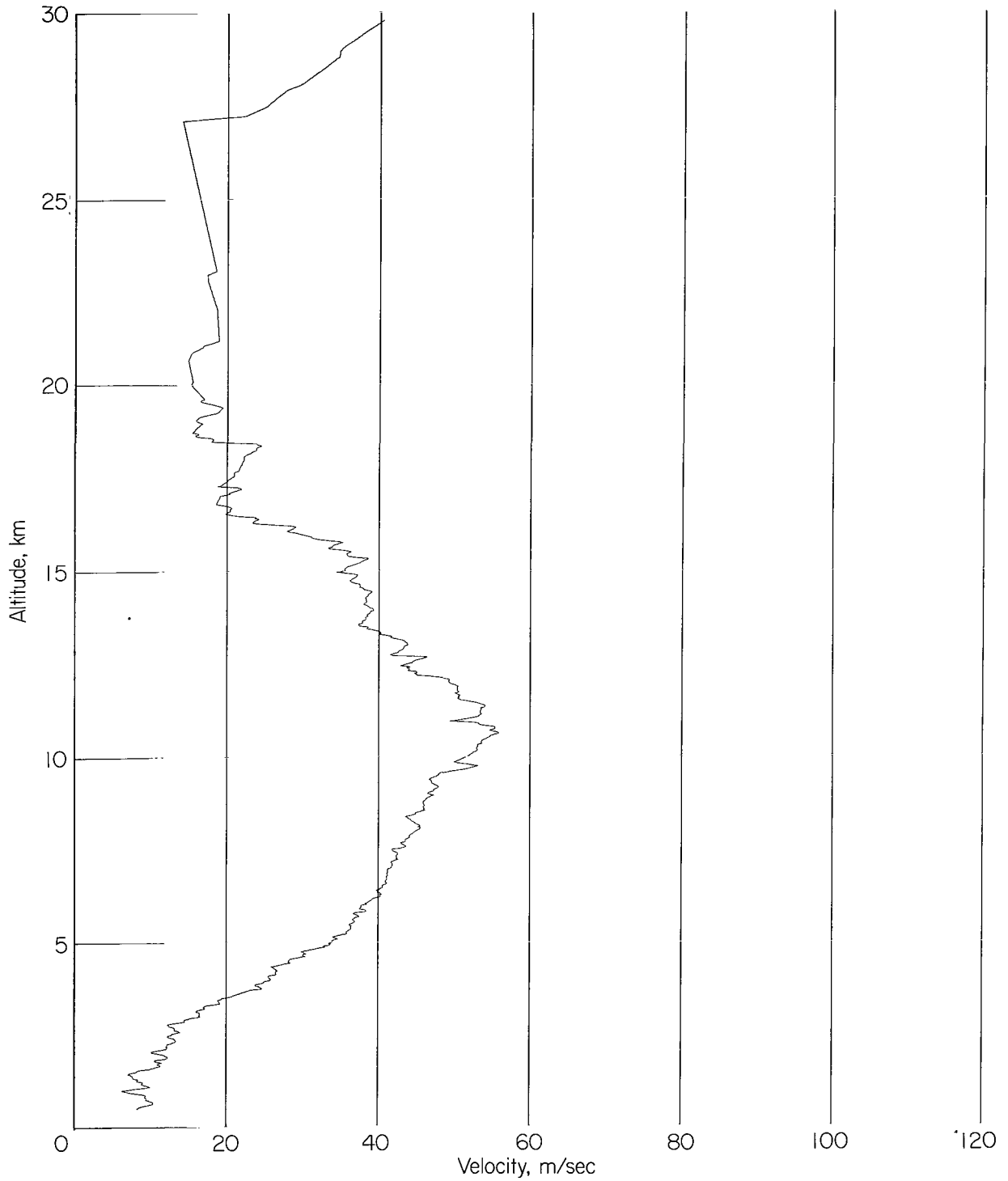
(a) West-to-east velocity component.

Figure 46.- Wind profile of smoke trail 071 obtained December 8, 1964. Time interval, 60 seconds; height interval, 25 meters.



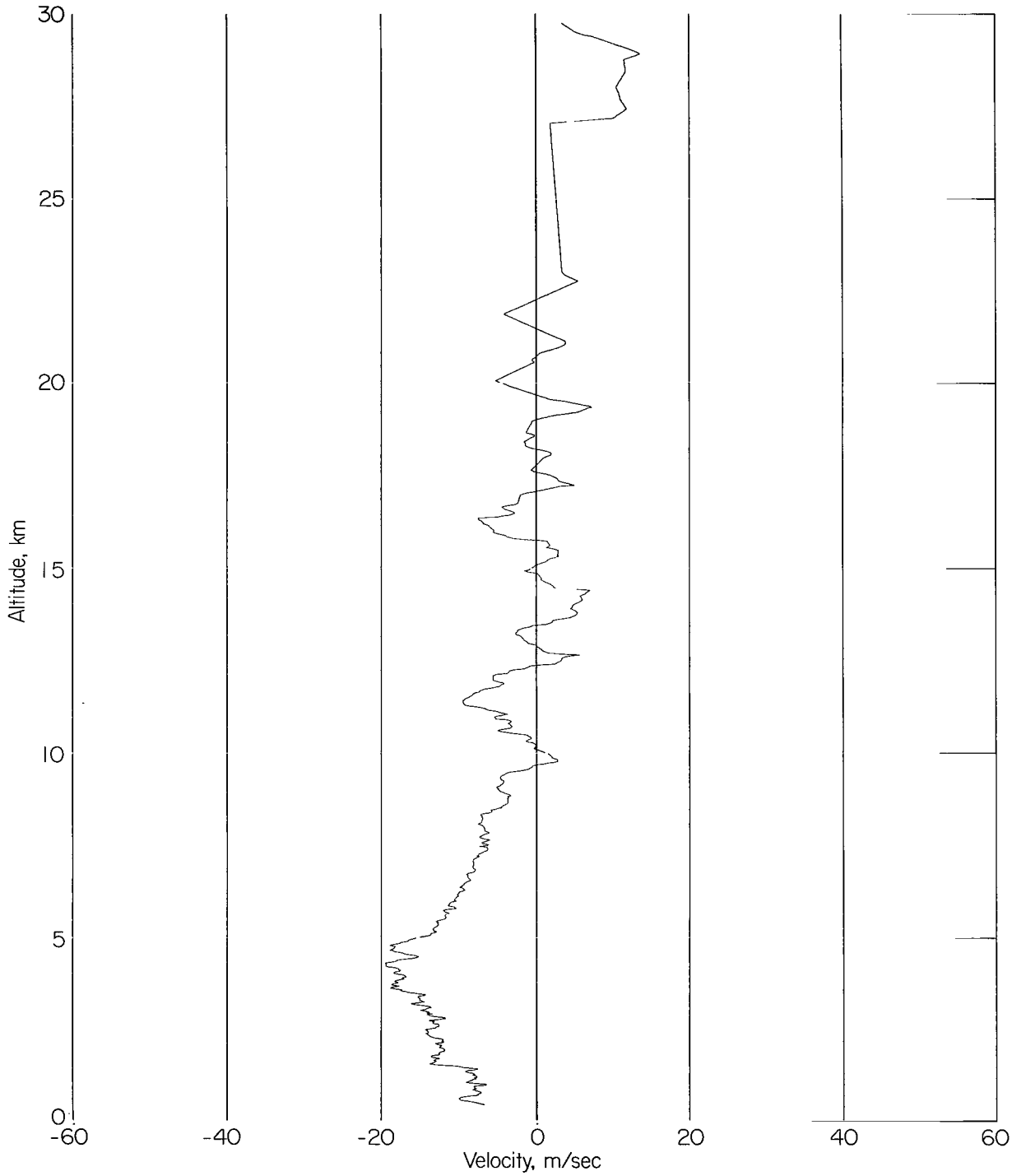
(b) South-to-north velocity component.

Figure 46.- Concluded.



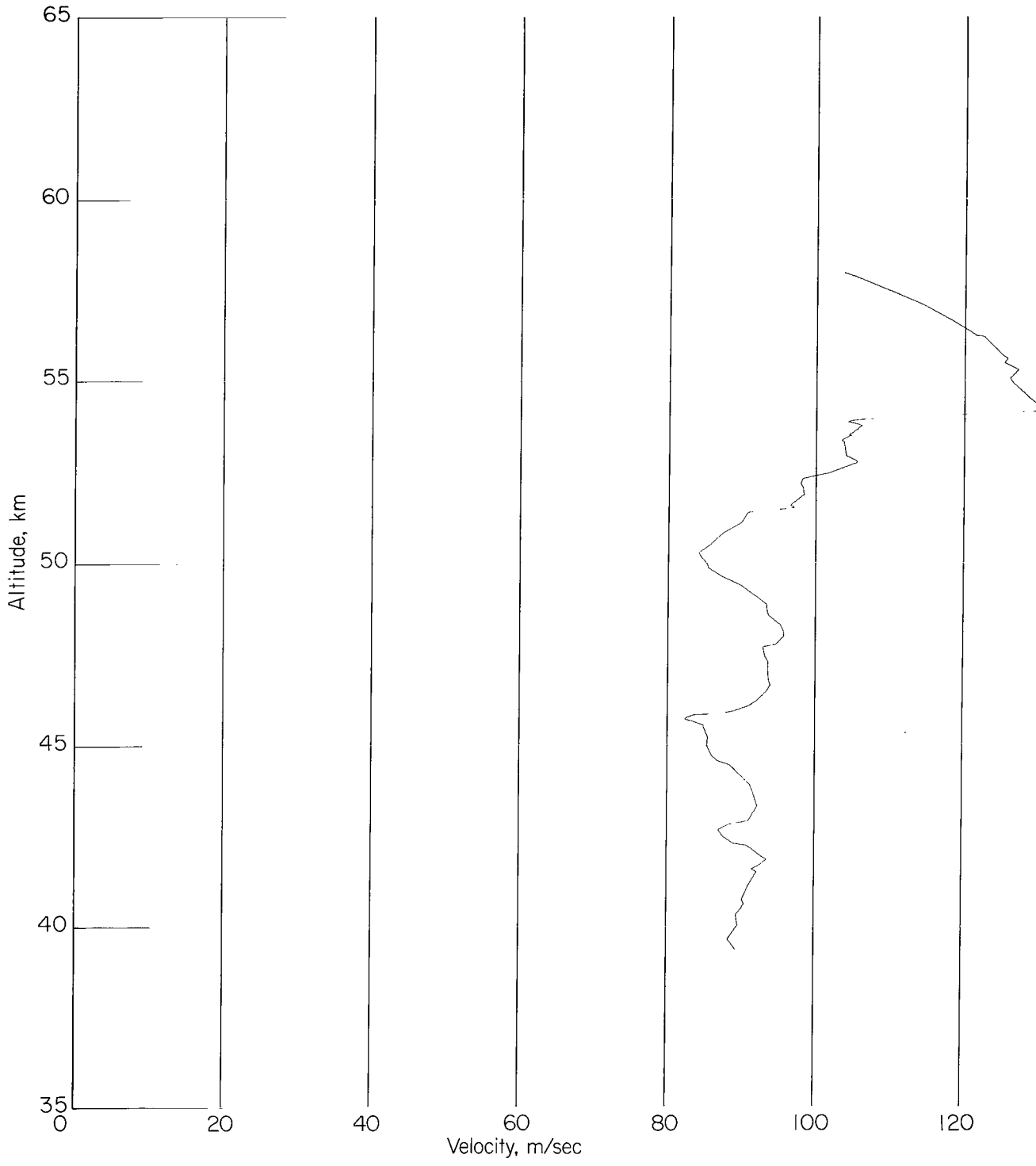
(a) First-stage west-to-east velocity component.

Figure 47.- Wind profile of smoke trail 073 obtained December 15, 1964. Time interval, 60 seconds; height interval, 25 meters.



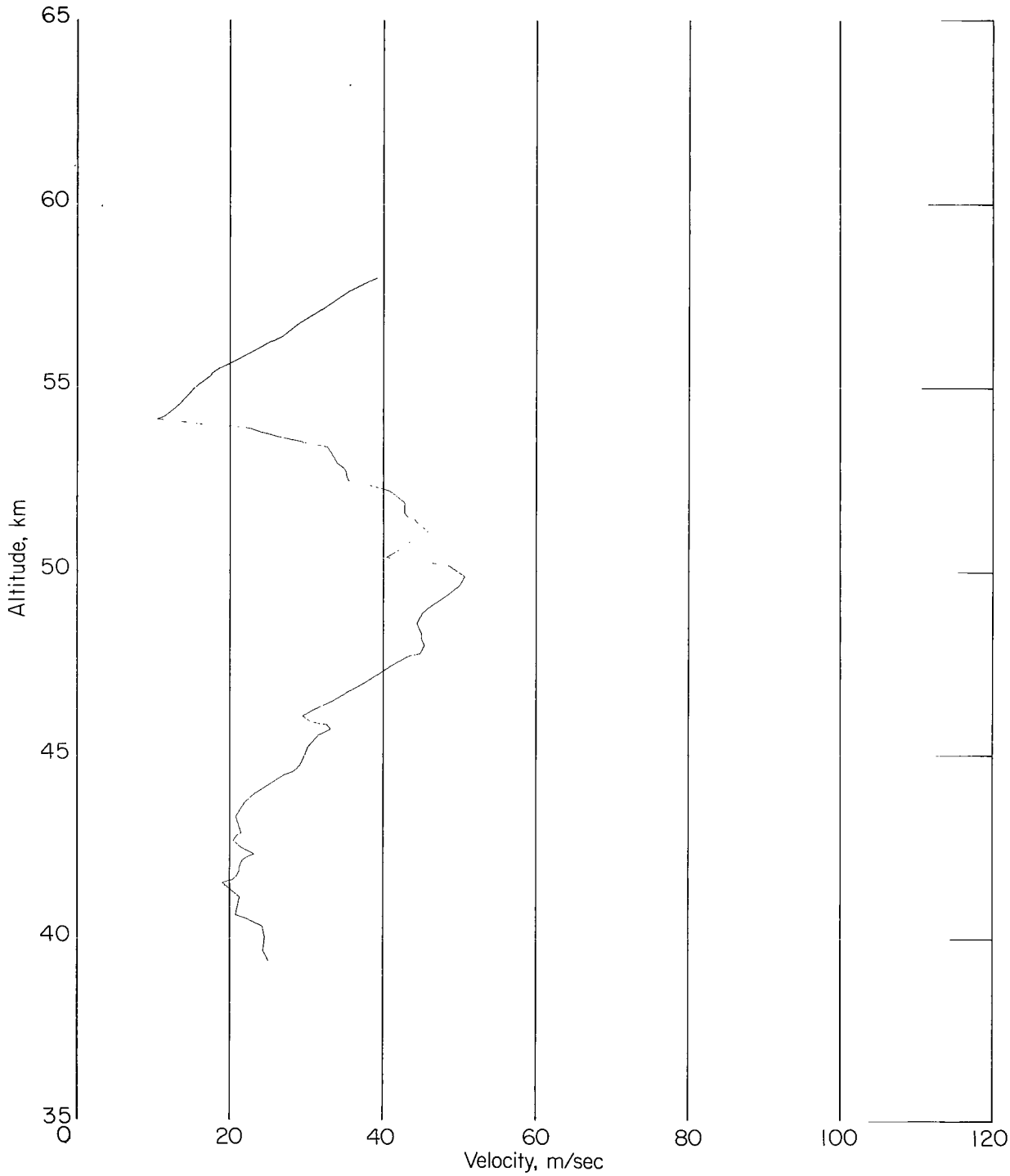
(b) First-stage south-to-north velocity component.

Figure 47.- Continued.



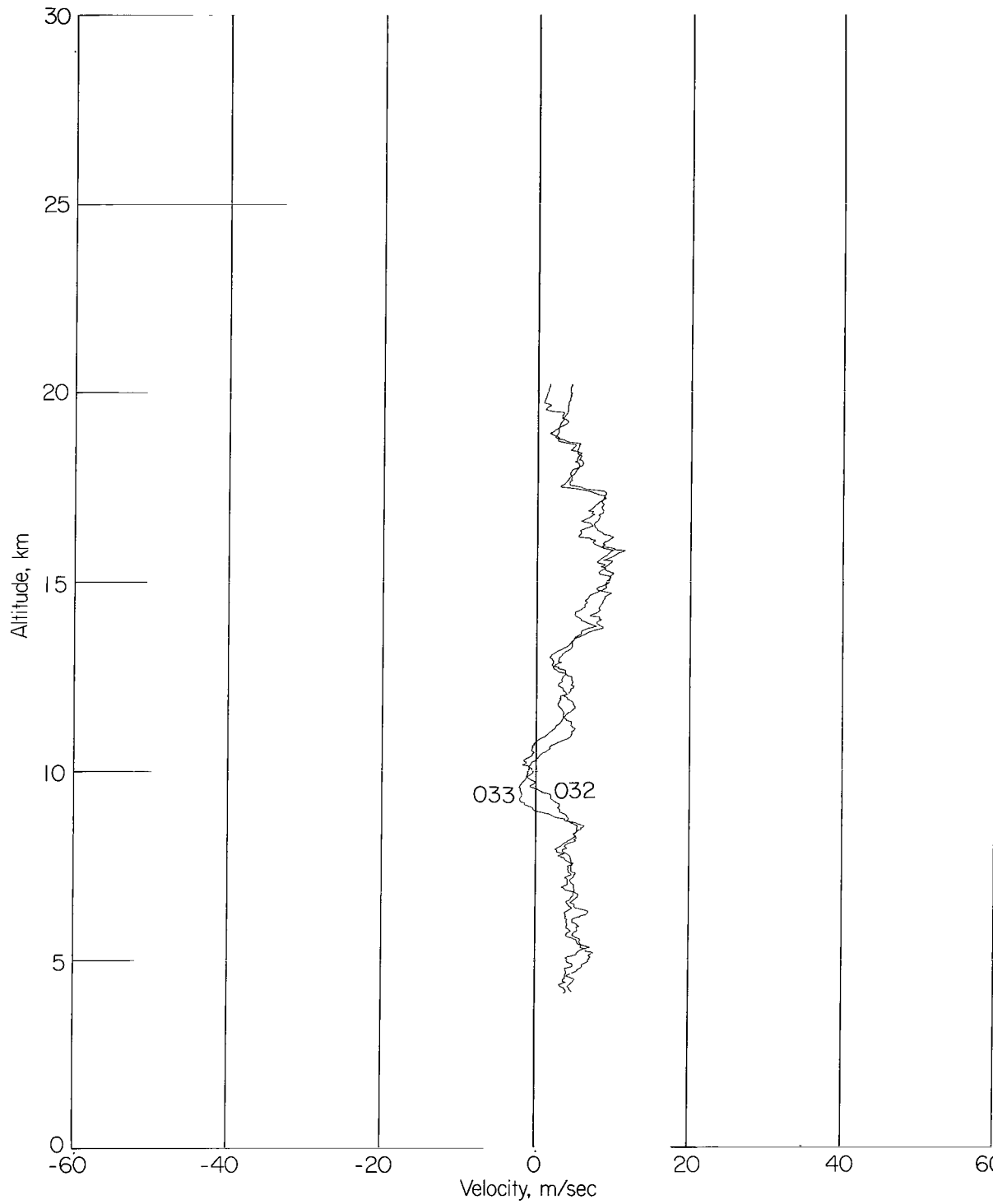
(c) Second-stage west-to-east velocity component.

Figure 47.- Continued.



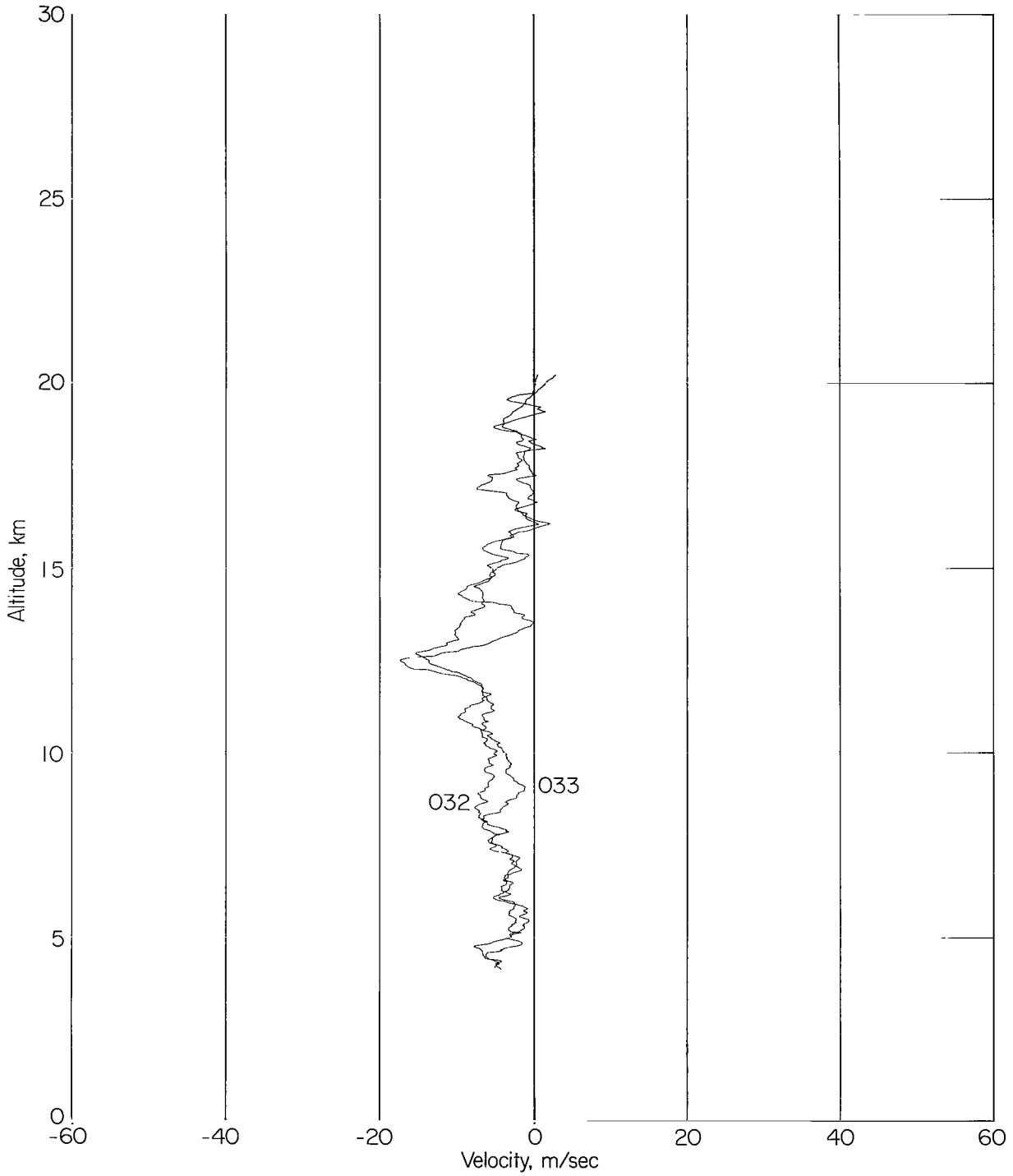
(d) Second-stage south-to-north velocity components.

Figure 47.- Concluded.



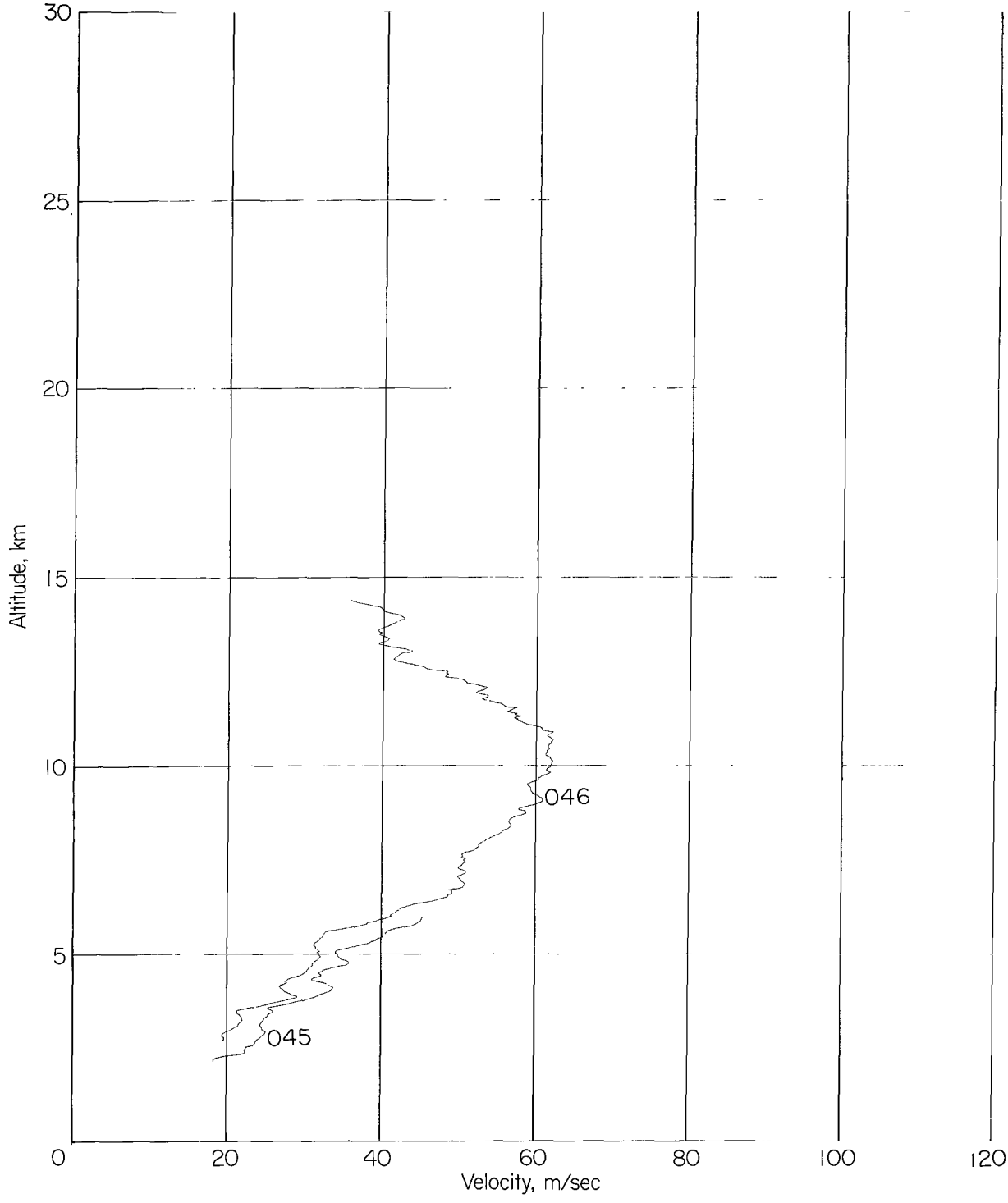
(a) West-to-east velocity component.

Figure 48.- Wind profiles of smoke trails 032 and 033 obtained September 19, 1963 at 1514 and 1648 EST.



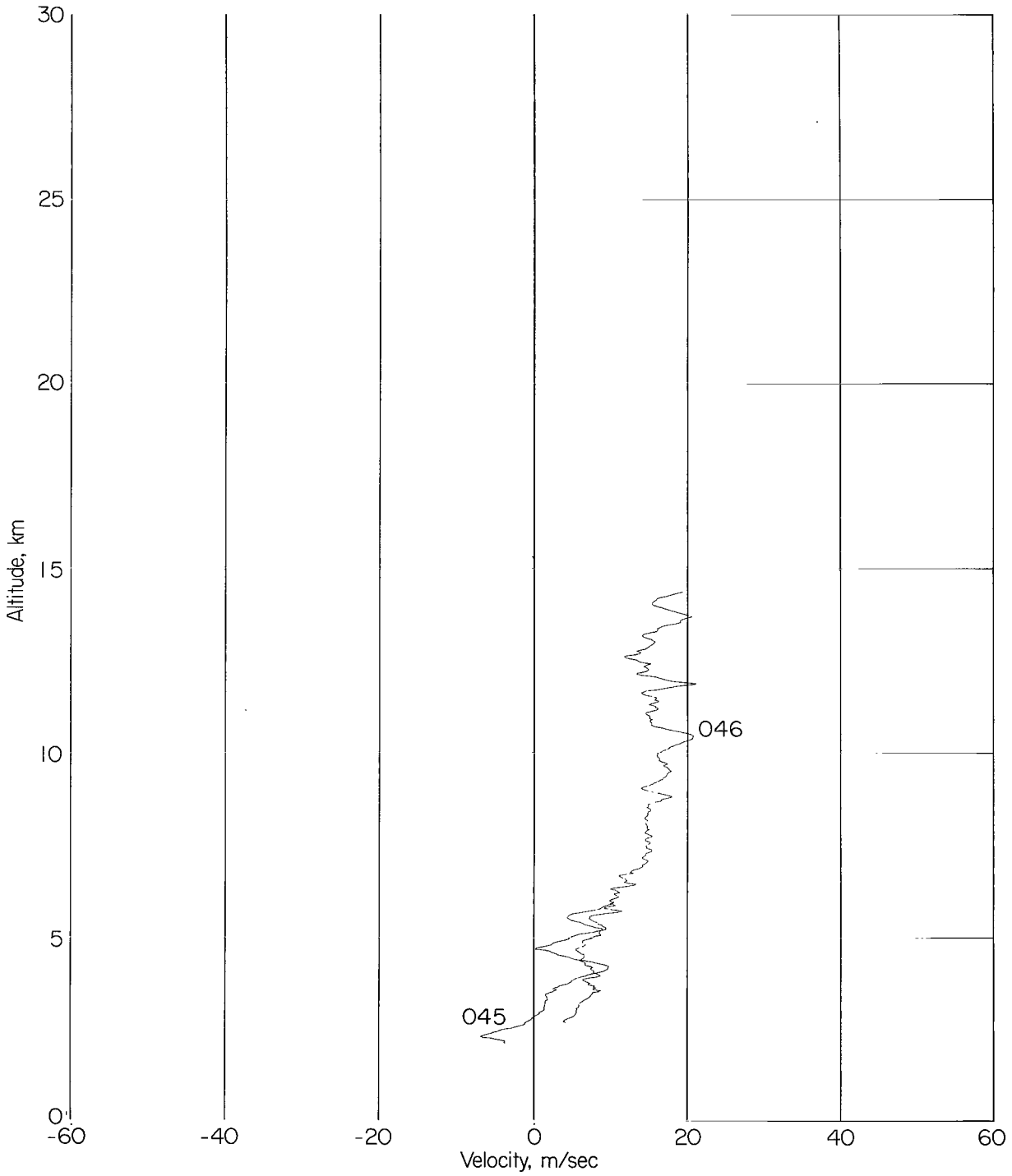
(b) South-to-north velocity component.

Figure 48.- Concluded.



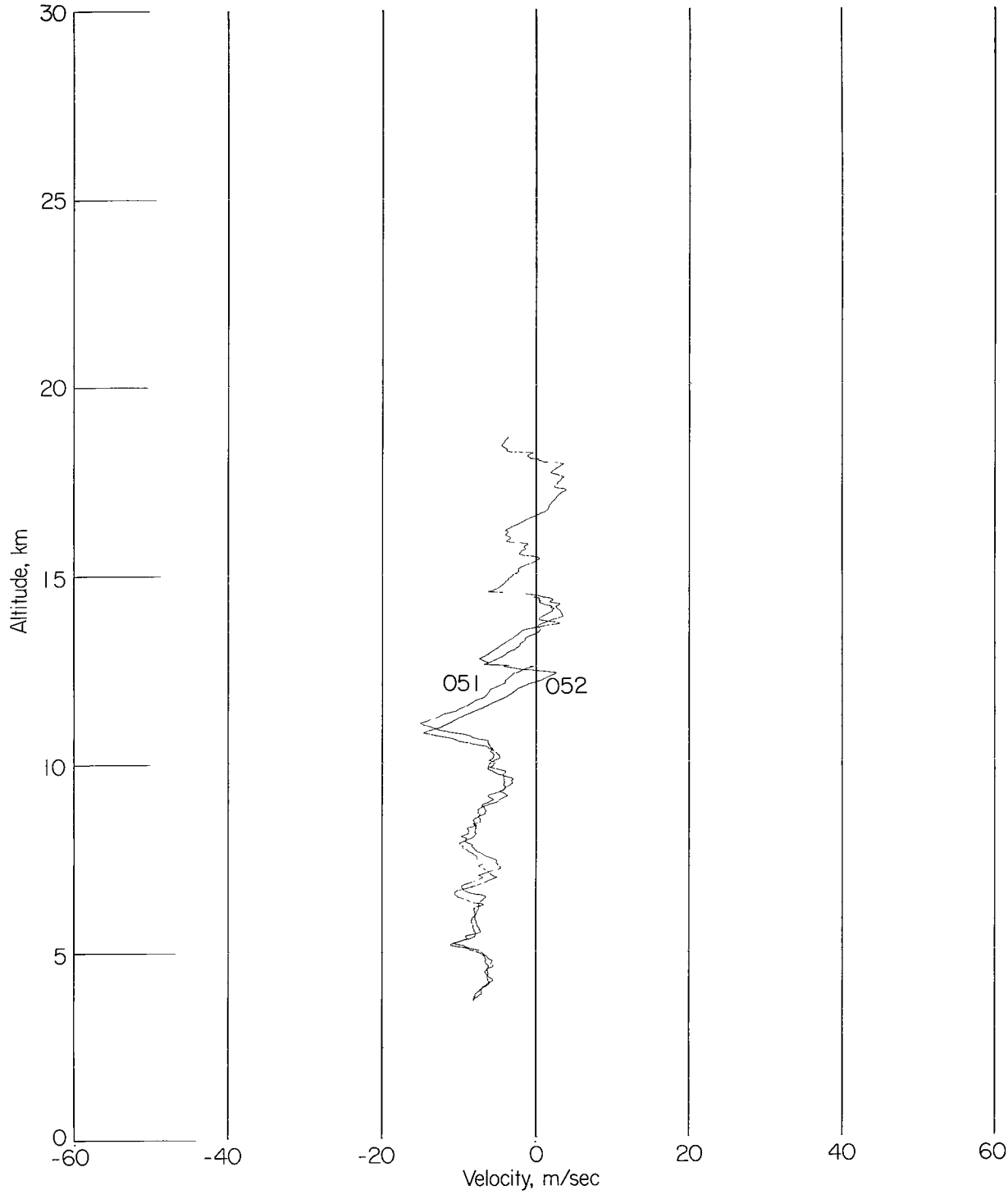
(a) West-to-east velocity component.

Figure 49.- Wind profiles of smoke trails 045 and 046 obtained March 27, 1964 at 1226 and 1404 EST.



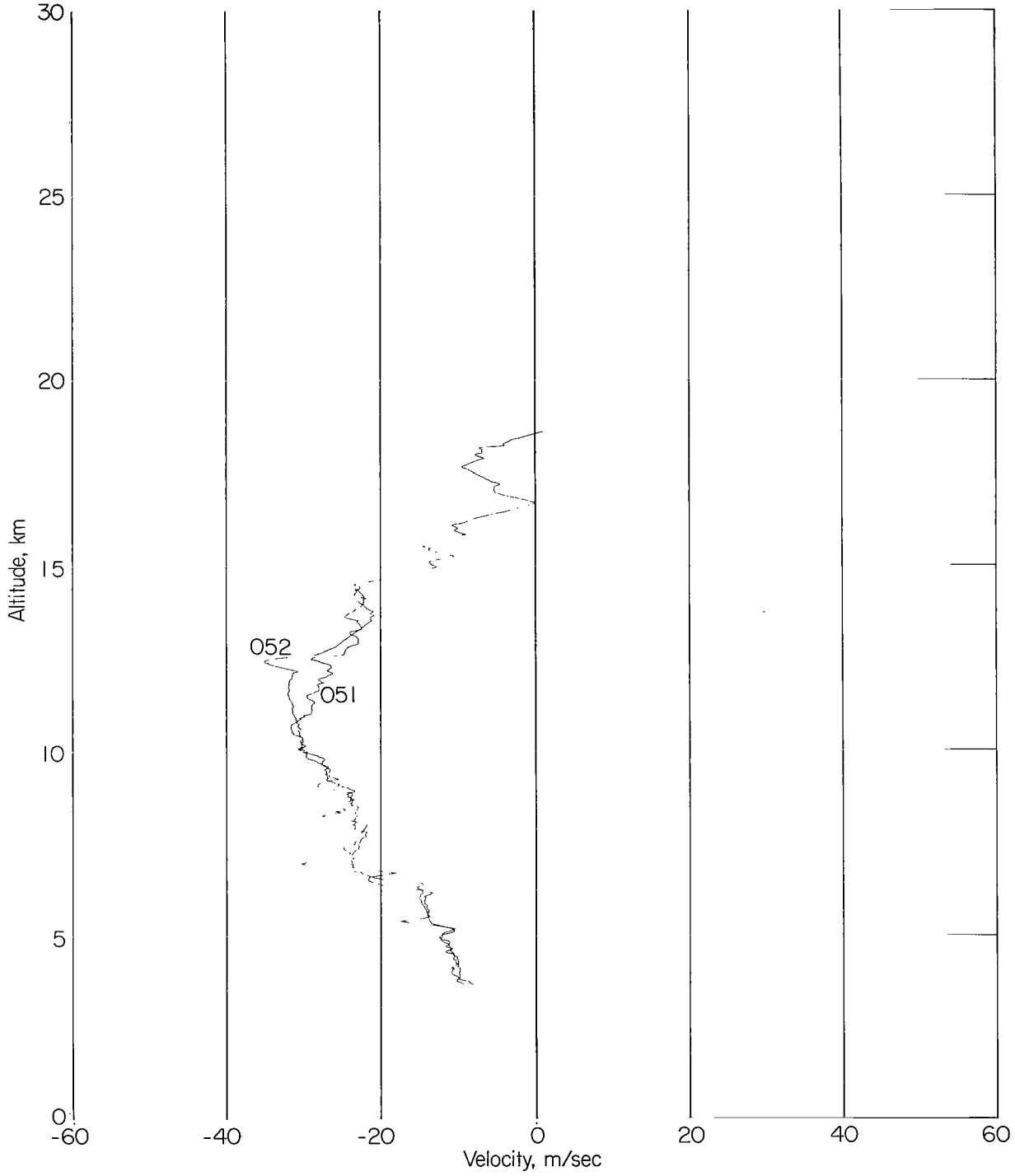
(b) South-to-north velocity component.

Figure 49.- Concluded.



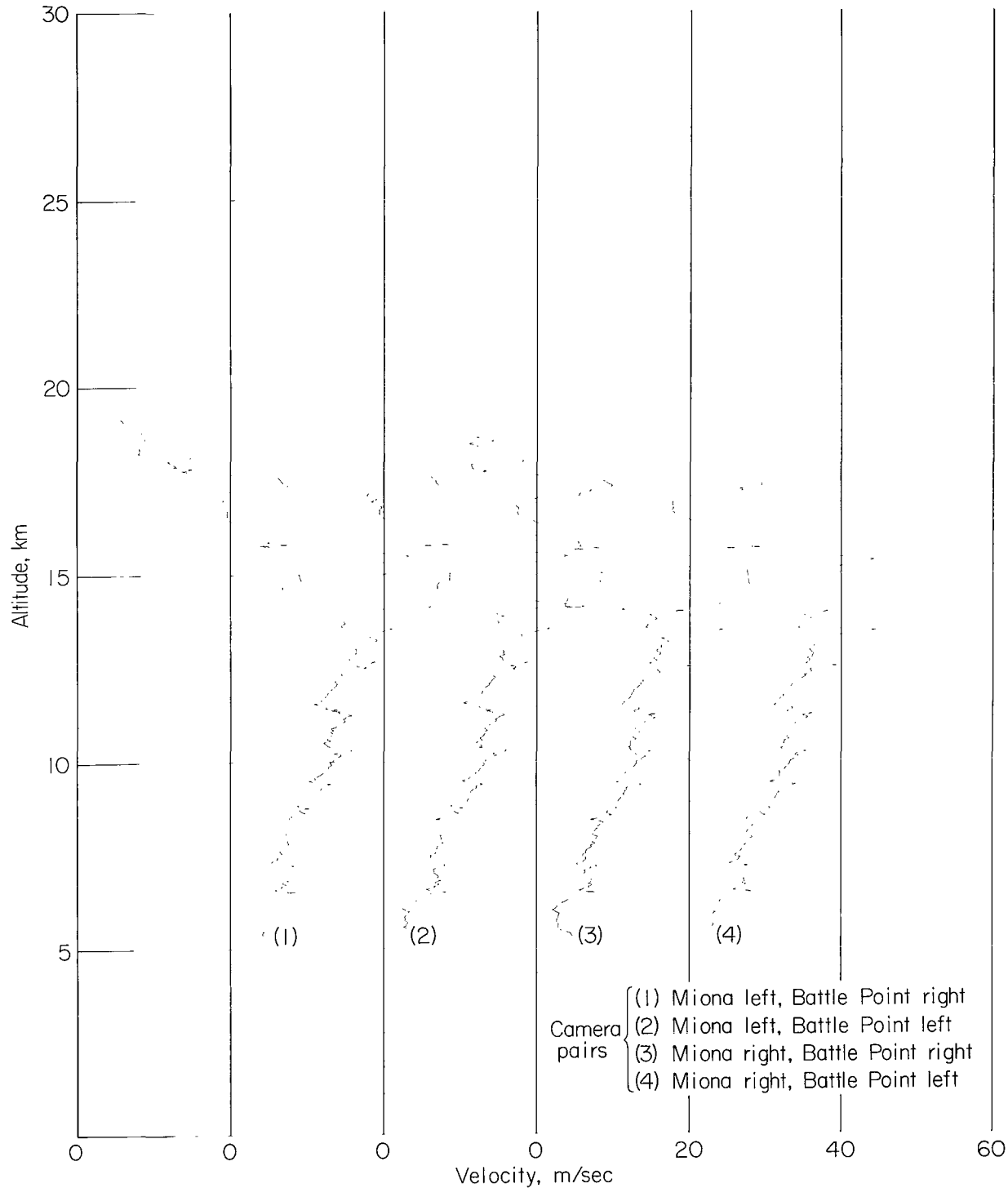
(a) West-to-east velocity component.

Figure 50.- Wind profiles of smoke trails 051 and 052 obtained May 6, 1964 at 1318 and 1343 EST.



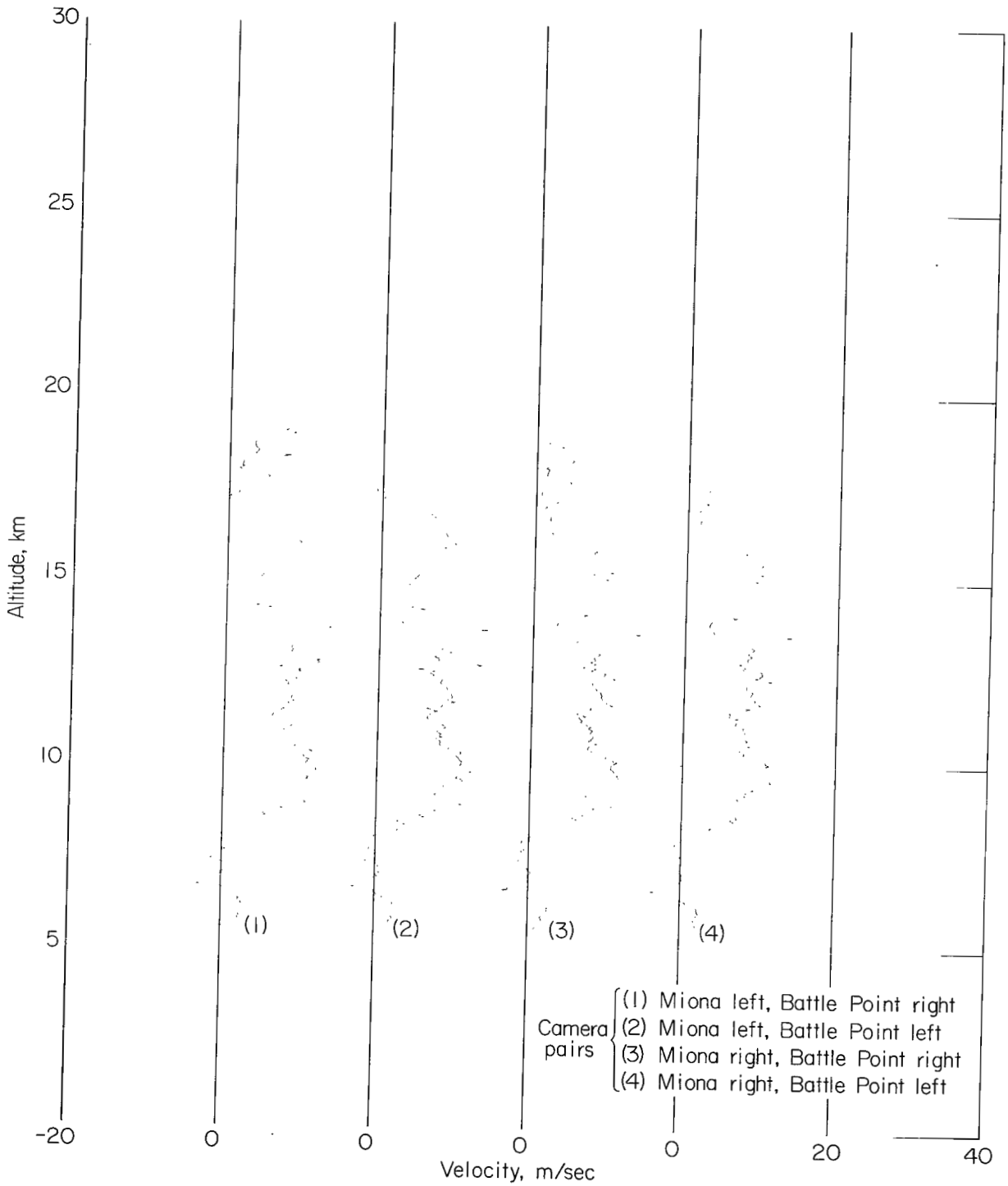
(b) South-to-north velocity component.

Figure 50.- Concluded.



(a) West-to-east velocity component.

Figure 51.- Comparison of smoke-trail 065 velocity profiles obtained by using different camera pairs.



(b) South-to-north velocity component.

Figure 51.- Concluded.

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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